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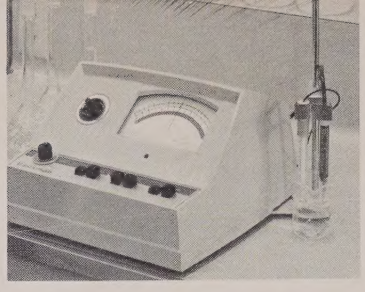
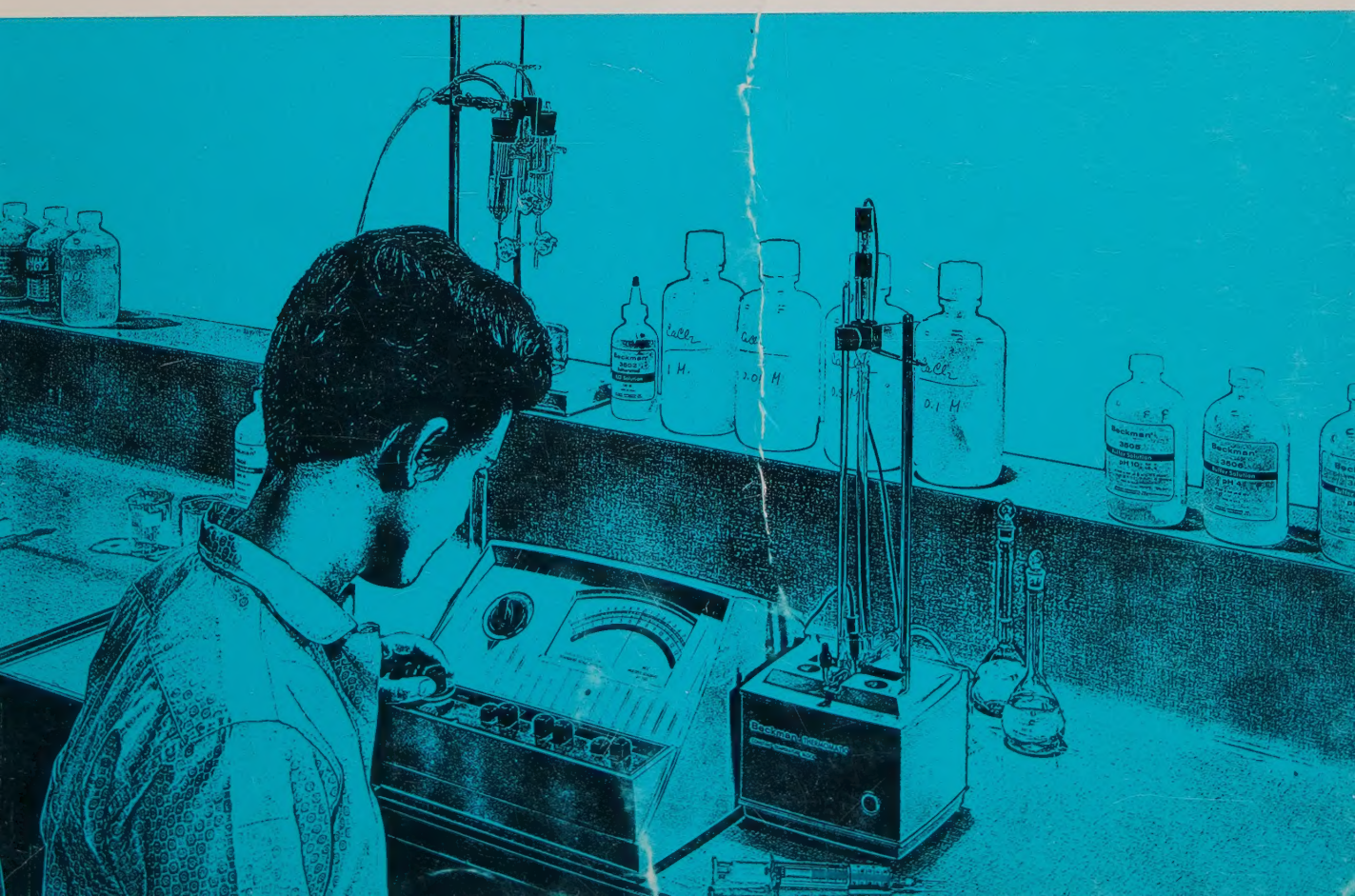


Beckman®

INSTRUCTION MANUAL

Model 76

Expanded Scale pH Meter



E. Trujillo – Writer
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J. E. Leonard
G. C. Blanke – Project Engineers
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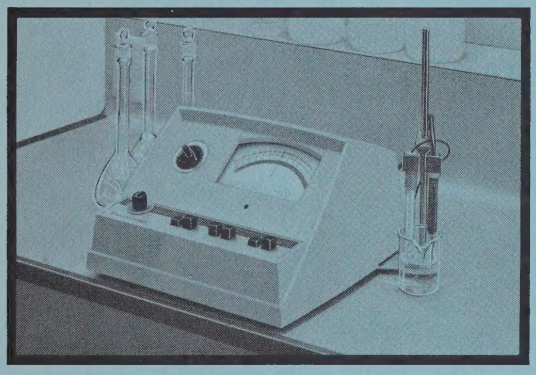
Model 76

Expanded Scale pH Meter Operation, Service and Maintenance



BECKMAN INSTRUMENTS, INC.
SCIENTIFIC INSTRUMENTS DIVISION
FULLERTON, CALIFORNIA 92634

April 1964 80694 14TW196 Printed in U.S.A.

Specifications

POWER SOURCE

Model 76000: 115 volts (±10%), 50-60 cycles, alternating current.

Model 76001: 230 volts (±10%), 50-60 cycles, alternating current.

STABILIZATION TIME

About 10 seconds.

pH RANGE

0 to 14 pH in standard scale operation, and any 2 pH span within the 0 to 14 pH range in expanded scale operation.

MILLIVOLT RANGE

Standard Scale:

Calibrated in 0 to ±1400 millivolt range. The scale may be shifted to permit measurements in the range between −2000 and +2000 millivolts.

Expanded Scale:

Calibrated over a 200 millivolt span. The scale may be shifted to include any 200 millivolt span within a ±1400 millivolt range.

ACCURACY

±0.01 pH and 1.0 millivolt (in expanded scale operation) when careful measuring techniques are employed.

REPEATABILITY

±0.003 pH and 0.3 millivolts (in expanded scale operation) when careful measuring techniques are employed.

SENSOR

Normally Beckman Glass and Reference or Metallic Electrodes, or Beckman Combination Electrodes.

PRESENTATION

Direct-reading meter.

TEMPERATURE COMPENSATION

Temperature compensation for pH measurements is made manually — or automatically by use of the Beckman 39096 Thermo-Compensator — throughout the 0° to 100° Centigrade range.

AMBIENT TEMPERATURE RANGE

−10° to 40° Centigrade.
(14° to 104° Fahrenheit).

RECORDER

Connections are provided for a potentiometric recorder with a sensitivity of 200 millivolts or less, or for a current recorder with a sensitivity of 204 microamperes or less.

Beckman

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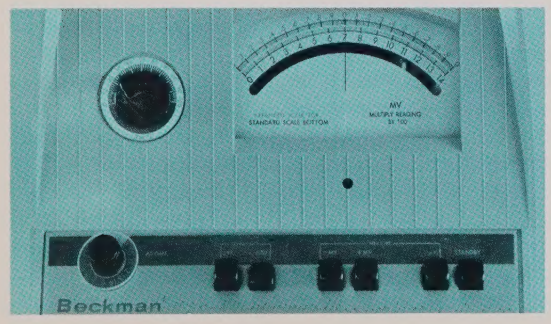
Section 1. Introduction

1.1 THE INSTRUMENT

The Beckman Expanded Scale pH Meter is a direct-reading laboratory instrument for making highly precise pH and potential measurements. Two scales — standard and expanded — are provided on the large meter face. The standard scale indicates the normal 0 to 14 pH and 0 to ±1400 millivolt ranges. The expanded scale, with graduations of 0.01 pH or 1 millivolt and a range of 2 pH or 200 millivolts, provides a seven-fold increase in reading accuracy over the standard scale. Zero position is adjusted for the scale in use. Thus, the 2 pH, 200 millivolt span on the expanded scale may be applied to any portion of the standard scale. This feature also allows shifting of the standard scale so that its ±1400 millivolt span can be applied between −2000 and +2000 millivolts (by use of an external potential source for calibration).

Measurements with a sensitivity of 0.003 pH and 0.3 millivolts are possible by employing careful techniques to standardize the meter and electrode system. Maximum error as a voltmeter (due to combined span and linearity errors) is 0.02 pH and 2.0 millivolts on the expanded scale, and 0.15 pH and 15 millivolts on the standard scale. Temperature compensation of pH electrodes is accurate to within 1°C in the 0° to 60°C range, and within 2°C in the 60° to 100°C range. A chopper amplifier with an alternating-current carrier provides automatic and continuous meter stabilization.



Push-button controls increase the rapidity and convenience with which measurements are conducted. Temperature corrections in the 0° to 100°C range are made manually — or automatically if the Beckman Thermo-Compensator is used with the instrument. Terminals are present for either a potentiometric or current recorder. The instrument circuit is completely transistorized, with the exception of one vacuum tube for the high impedance input. (This particular vacuum tube has a greater life expectancy than the transistors.)

Standard Beckman Glass or Metallic and Reference Electrodes are normally employed with the instrument. A wide variety of electrodes are available for specific applications. A polarizing-current terminal on the instrument allows the determination of titration end-points for Karl Fischer, Bromine Number, and similar reactions.

The Expanded Scale pH Meter is operated on alternating current (50-60 cycles) except for asymmetry correction and zero suppression, which utilize a mercury battery. The Model 76000 pH Meter operates on 115 volts ±10%, while the Model 76001 pH Meter requires a line potential of 230 volts ±10%. Either instrument may be used on other line potentials if an appropriate step-up or step-down autotransformer or transformer (15 VA, or more) is used externally.

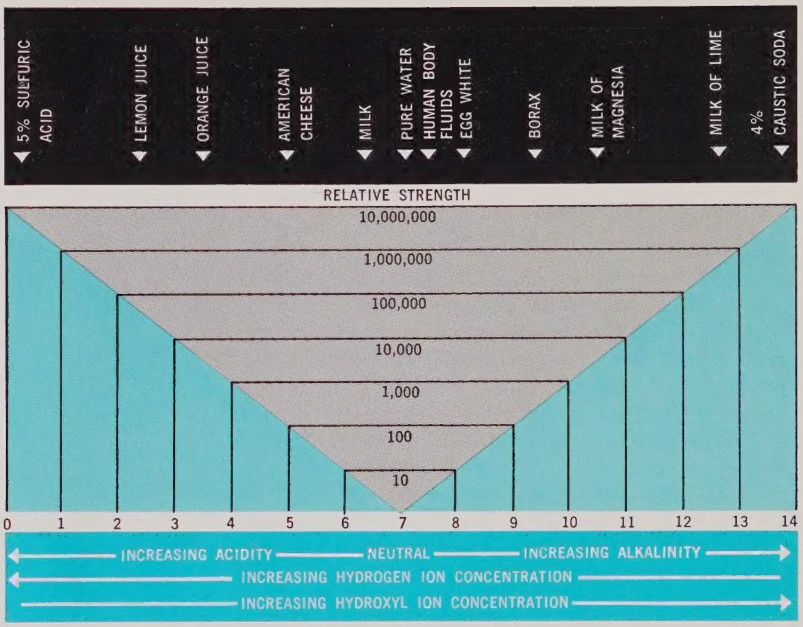


Figure 1. The pH Scale

Section 2. Principles of pH Measurement

2.1 THE pH SCALE

In its simplest definition, pH can be described as a measure of the acidity or alkalinity of a substance. For instance, lemon juice is acid and lye is alkaline. The pH scale is used to express the degree.

There are many hundreds of acids and alkalies of varying strength. Despite their widely diverse properties, aqueous solutions owe their acidity to dissociated, or free, hydrogen ions (H^+) in solution; while they owe their alkalinity to dissociated hydroxyl ions (OH^-) in solution. However, all acid solutions have some hydroxyl ions, just as all alkaline solutions have some hydrogen ions, and the product of the two ions in a given solution is always a constant. Therefore, it is possible to express the concentration of one ion relative to the other, rather than have a separate scale for each.

Hydrogen ion concentration is used to express both acidity and alkalinity, since an electrode that will sense hydrogen ion concentration is much more stable than one which will sense hydroxyl ion concentration. Because numerical values for the hydrogen ion concentration often are extremely small fractions (for example, 1/10,000,000), the pH unit is used instead. This unit is defined as the negative of the logarithm (or the log of the reciprocal) of the hydrogen ion concentration. The arbitrary term, pH, is simply a logarithmic index employing small numbers to express hydrogen ion concentration.

The pH scale extends from 0 to 14, with 7 — the pH of pure water at 25°C — the neutral point at which hydrogen ions and hydroxyl ions exist at the same concentration. Numbers greater than 7 indicate the degree of alkalinity, and numbers less than 7 indicate the degree of acidity. The relationship between the two ions and acidity and alkalinity is shown in Figure 1. Note that the relative strength of acids and alkalies changes tenfold for each unit change in pH. Thus, compared with a solution of pH5, a solution of pH4 is ten times as acid, a solution of pH3 is a hundred times as acid, and a solution of pH2 is a thousand times as acid.

2.2 MEASURING PROCESS

The Expanded Scale pH Meter indicates the hydrogen ion concentration in a test solution by responding to the potential developed by an electrical cell. The cell consists of two electrodes — a Beckman Glass Electrode and a Beckman Reference Electrode — immersed in the test solution.

The glass electrode (Figure 2) consists of an internal sealed tube with a metallic tip (typically of silver-silver chloride) and an external tube containing a standard solution. A pH-sensitive glass bulb forms the immersion end of the electrode. Various types of pH-sensitive glass are used for different applications. The potential of the glass electrode is proportional to the pH of the solution in which it is immersed.

The reference electrode (Figure 2) develops a constant electrical potential against which the potential of the glass electrode can be measured. It consists of an internal element (typically of silver-silver chloride) and an outer glass body which is filled with an electrolyte solution. This solution establishes a stable constant potential at the internal element and acts as an electrolytic conducting bridge between the element and the test solution. This electrical connection is maintained by a flow of electrolyte solution from the electrode to form a liquid junction. Three basic types of junctions are available: ground glass sleeve, porous fiber and palladium annulus. In order to minimize the electrical potential developed at the liquid junction, concentrated potassium chloride solution is generally used as the electrolyte.

In the measurement of pH, the electrodes are first immersed in a buffer solution of known pH. The pH meter zero point is adjusted by turning the Asymmetry Control until the pH value of the buffer is shown by the meter. This standardization automatically compensates for the various potentials in the electrode system shown in Figure 2. Subsequent immersion of the electrodes in a test solution causes a potential, E_3, that is proportional to the pH of the solution. This potential registers directly as pH on the standard or expanded scale of the Expanded Scale pH Meter.

For a more thorough discussion of pH and electrochemical determination, the following publications are recommended:

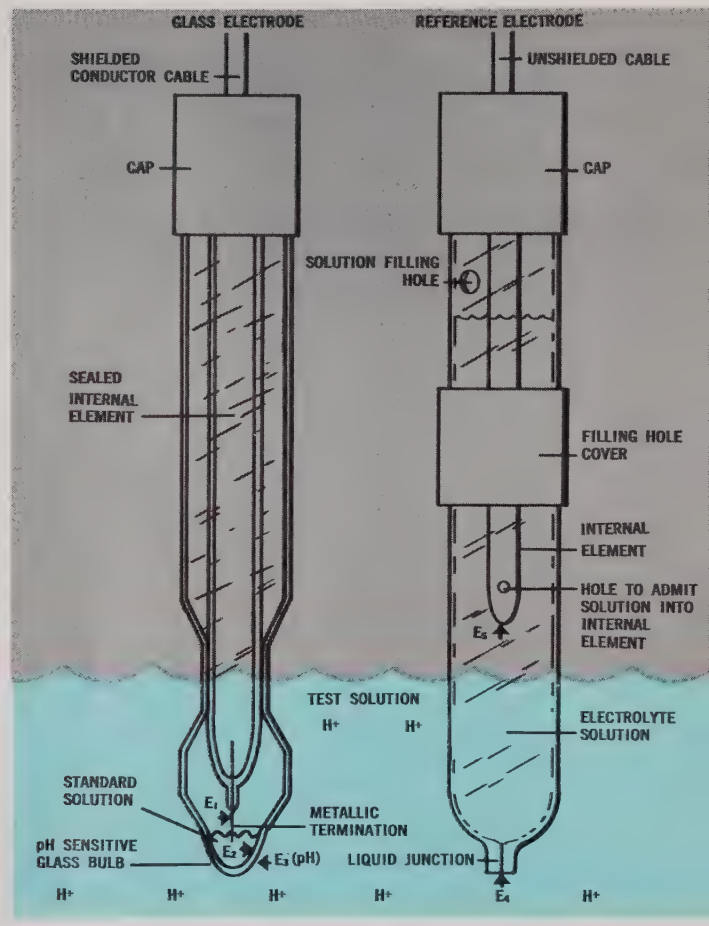


Figure 2. The Electrode System

E_1 — potential between the internal element and the standard solution.
E_2 — potential between the standard solution and the inner surface of the glass membrane.
E_3 — potential between the outer surface of the pH-sensitive glass bulb and the test solution. This is the only potential in the electrode system that varies in accordance with change in hydrogen ion concentration, or pH, of the test solution.
E_4 — potential of the liquid junction between the electrolyte and test solutions.
E_5 — potential developed at the internal element in electrolyte solution.

Bates, R. G., *Electrometric pH Determinations*, Wiley, New York, 1957.

Kolthoff, I. M., and Laitinen, H. A., *pH and Electro Titrations*, Second Edition, Wiley, New York, 1940.

Section 3. Preliminary Procedure

3.1 ELECTRODE HOLDER INSTALLATION

The electrode holder (Figure 3) consists of an electrode clip, a support rod, and a bracket for attaching the rod to the instrument. This must be installed before placing the instrument in operation.

To attach the holder, first invert the instrument. Place the bracket over the mounting holes in the chassis and fasten with the screws provided. Turn the instrument upright and attach the support rod to the bracket. Slide the electrode clip onto the support rod.

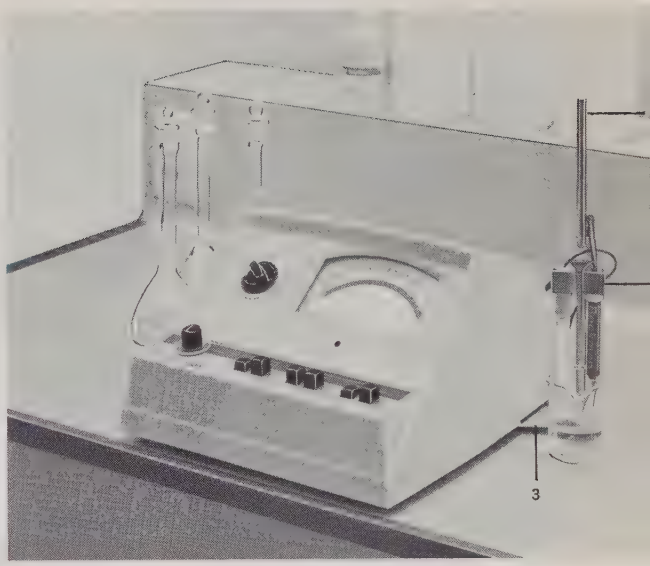


Figure 3. Expanded Scale pH Meter Assembly

1 SUPPORT ROD
2 ELECTRODE CLIP
3 MOUNTING BRACKET

3.2 ELECTRODE PREPARATION

The electrodes — glass and reference — mount in the electrode holder so that the spring clip fastens firmly to the cap at the top of each electrode. If the thermo-compensator is used, mount it in the same manner in the electrode clip between the two electrodes. Attach the leads to the appropriate terminals on the terminal board (Figure 6) at the rear of the instrument. Insert the lead ends as far as possible in the terminals. Tighten the setscrew on the glass electrode (INPUT) terminal in the top groove of the lead end to keep the electrode in correct electrical contact with the instrument.

Remove the protective caps from the electrode tips. Check to see that the electrodes are properly prepared before commencing operation. The pH-sensitive bulb portion of the glass electrode must be soaked several hours in distilled water or in a buffer solution before stable measurements may be obtained. Thereafter, between measurements, leave the tip of the electrode immersed in distilled water.

Slide the reference electrode sleeve downward to expose the filling hole, and determine that the electrolyte solution is at a sufficient level. Note that the filling hole must remain uncovered during operation to ensure a uniform flow of electrolyte solution through the liquid junction. Make sure that the electrolyte flows through the junction. When the electrode is to be idle for longer than just a few minutes, immerse the tip in the electrolyte solution with which the electrode is filled. This will keep the junction in a free-flowing condition.

For further information concerning the electrodes, refer to Paragraph 11.2 and 12.6 of this publication and the instruction sheet supplied with each electrode.

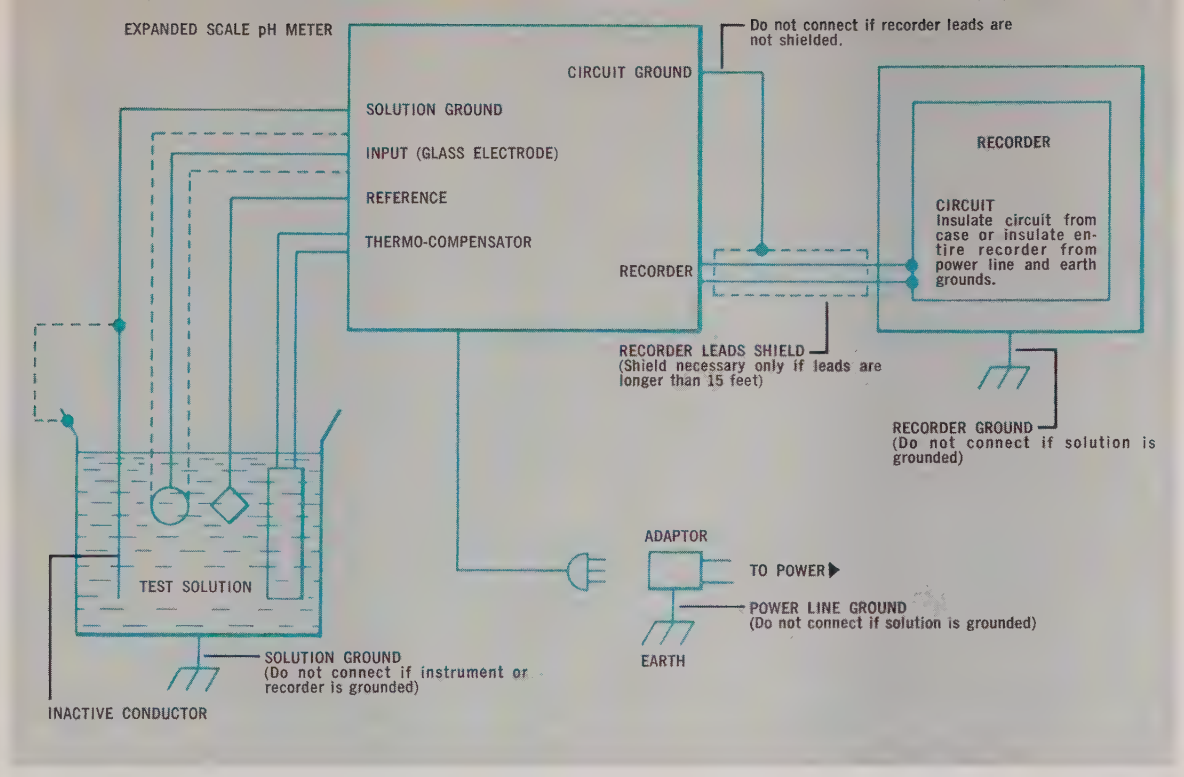


Figure 4. Instrument and Solution Grounding Connections

3.3 INSTRUMENT GROUNDING

The power cord on the Expanded Scale pH Meter is a three-conductor cable, provided with a three-pronged plug. To ensure greatest stability of operation, and to lessen personal hazard, the instrument case connects to earth ground by means of the grounding pin in the power plug. A special adaptor to ground the power cord is provided for use when the electrical outlet does not have a third (ground) contact. When using the adaptor, connect the pigtail lead to a water pipe or other good earth ground — except when instructed otherwise, as in Paragraph 3.4. Figure 4 shows the grounding connections.

3.4 SOLUTION GROUNDING

An accurate measurement cannot be obtained if a direct-current connection between the instrument and the sample solution occurs by any means other than by the electrodes. This situation would exist, for example, if the instrument were grounded through its power cord while the sample is in a metallic container which is not isolated from ground. To avoid this situation when the sample cannot be isolated readily, use the power cord adaptor, regardless of the type of outlet, and leave the ground lead from the adaptor disconnected.

In addition, if the electrodes are to be used in a grounded system, establish a connection between the test solution and the SOLUTION GROUND terminal. This connection to the test solution may be made through a metallic container, tubes or pipes in direct contact with the test solution or, if a non-metallic system is used, through platinum or another inactive conductor immersed in the solution. Make the connection near the point at which the electrodes are immersed in the test solution. The grounding connections are shown in Figure 4. When the solution is grounded, be sure that the instrument is well insulated from ground.

3.5 METER NEEDLE ADJUSTMENT

It is necessary for the mechanical zero of the meter needle to be set properly. With the power cord disconnected from the power line, check the meter reading. The meter needle should be exactly over the center zero on the expanded scale (7 on the standard scale.) If it is not at this position, set it correctly by using a screwdriver to turn the Meter Adjustment Control.

NOTE

When taking a meter reading, always observe the needle so that it covers its own reflection in the scale mirror; otherwise parallax will cause inaccuracies.

Section 4. Instrument Controls

The operating controls (Figure 5) regularly employed for pH and millivolt measurements are arranged on the front of the instrument. Six are push-button switches that provide convenience and rapidity in making measurements. These are mounted in pairs, with the appropriate ones mechanically linked for mutual interaction. In addition, a Thermo-Compensator Switch is mounted on the back of the instrument.

4.1 ASYMMETRY CONTROL

This control, identified ASYMM on the instrument panel, is a potentiometer which varies the input potential. The control establishes a correct pH reading when the instrument is standardized with buffer solutions by compensating for variations in electrode zero-potentials. It also is used to set a desired zero position for scale shifting. An adjustment range of 1300 millivolts is provided by the control when the mercury battery is fresh.

4.2 RANGE INDICATOR

The Range Indicator, a manually-set dial held by the Asymmetry Control, is provided to indicate the portion of the standard scale that is selected for expansion on the expanded scale. Always set the indicator to show the three prime figures of the 2 pH or 200 millivolt span to be expanded and refer to the setting when the reading on the expanded scale is interpreted. Examples of the use of the Range Indicator are given in Figures 8, 9 and 10.

4.3 EXPANDED SCALE SELECTOR

This push-button (EXP), when depressed, places the instrument in expanded scale operation. At this setting, instrument sensitivity is increased sevenfold over standard scale operation and readings are to be made on the red (upper) scale of the meter. The scale covers any 2 pH or 200 millivolt span that may be selected by scale shifting techniques while this push-button is depressed.

4.4 STANDARD SCALE SELECTOR

The instrument registers on the standard scale when this push-button (STD) is depressed. At this setting, unless the scale is shifted, the instrument registers on the black (lower) scale of the meter, covering the 0 to 14 pH and 0 to ±1400 millivolt ranges.

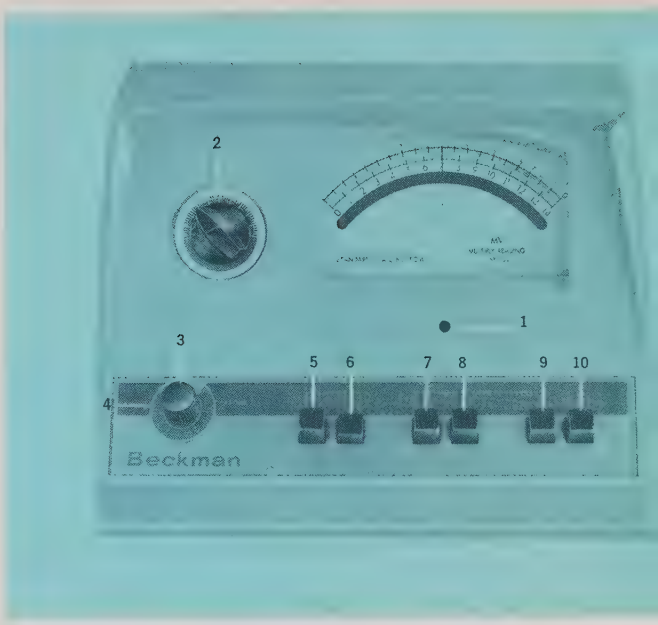


Figure 5. Operating Controls

1 METER ADJUSTMENT CONTROL
2 TEMPERATURE COMPENSATOR CONTROL
3 ASYMMETRY CONTROL
4 RANGE INDICATOR
5 EXPANDED SCALE SELECTOR
6 STANDARD SCALE SELECTOR
7 NEGATIVE MILLIVOLT SELECTOR
8 POSITIVE MILLIVOLT SELECTOR
9 pH SELECTOR
10 STANDBY SELECTOR

4.5 MILLIVOLT SELECTORS

These two push-buttons (−MV and +MV) place the instrument in operation for millivolt measurements. When +MV is pressed, readings at the right of the scale are more positive than readings at the left. When zero is on scale, and the +MV button is pressed, readings to the right of the zero-millivolt point are positive, while readings to the left are negative. The polarities are the opposite with the −MV button depressed.

4.6 pH SELECTOR

This push-button (pH) is depressed to make pH measurements with the instrument. At this setting, pH is read from 0 to 14 on the standard scale, and any selected 2 pH span in the 0 to 14 pH range on the expanded scale.

4.7 STANDBY SELECTOR

With the STANDBY button depressed, the amplifier input is shorted and the glass electrode lead is electrically disconnected. At this setting, violent displacement of the meter needle is prevented during such procedures as changing the electrodes from buffer to test solution. The setting also keeps the electrodes from being polarized by current generated when the electrodes are removed and rinsed or wiped. Power is supplied to the amplifier at this setting so that stable measurements may be made without a waiting period. Unless the instrument is to remain idle for an extended period, leave the STANDBY button depressed and the power cord connected. In an environment with high relative humidity, always leave a.c. power connected and the instrument in STANDBY operation when idle.

4.8 METER ADJUSTMENT CONTROL

The Meter Adjustment Control is a screwdriver-adjusted control in the cover of the meter and is reached through a small hole located directly below the meter face. This control permits resetting of the meter needle to its proper mechanical zero position — at 7 on the standard scale (the center zero on the expanded scale). Unplug the instrument before making the adjustment.

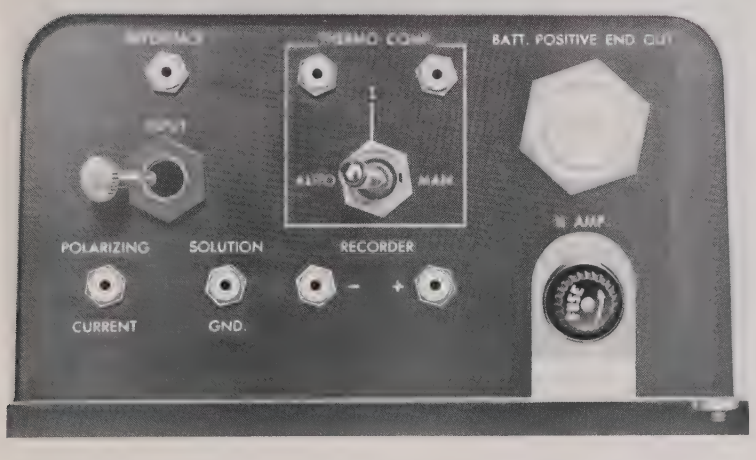
4.9 TEMPERATURE COMPENSATOR CONTROL

The electrode potential per pH unit changes directly with temperature by approximately 0.2 millivolts per degree Centigrade. Unless the effect of the temperature is compensated for, the pH reading will be incorrect. By changing the sensitivity of the instrument circuit, the Temperature Compensator Control provides compensation over the range from 0°C to 100°C. For the control to be operative, the Thermo-Compensator Switch must be in the MAN position. If the instrument is equipped with the Beckman 39096 Thermo-Compensator and the Thermo-Compensator Switch is in the AUTO position, temperature compensation is performed automatically. When the pH Meter is in expanded scale operation, both means of temperature compensation are accurate over the 6 to 8 pH range. Complete compensation is not provided over other expanded pH ranges because the scale shift potential is not temperature compensated. See Paragraph 5.1.

Since temperature compensation is not necessary for millivolt measurements, the Temperature Compensator Control is automatically excluded from the circuit when either of the MV push-buttons is depressed.

4.10 THERMO-COMPENSATOR SWITCH

This switch (Figure 6), located in the center of the terminal board at the rear of the instrument, has two settings. At one position (MAN), the Temperature Compensator Control is in the pH measuring circuit and operative so that temperature compensation may be performed manually. The other position (AUTO) is employed when the instrument is equipped with the Beckman Thermo-Compensator and temperature compensation of the pH measuring circuit is made automatically.



1. THERMO-COMPENSATOR SWITCH

Figure 6. Terminal Board

Section 5. Scale Shifting Procedure

The process of scale shifting consists of moving the position of zero relative to the calibrated range on either expanded or standard scales and is accomplished by turning the Asymmetry Control. This process is called standardization when applied to the pH scale.

5.1 pH SCALE

The first step in the measurement of pH is the establishment of a point of reference by a standardization procedure. To standardize the Expanded Scale pH Meter, it is necessary to place the electrodes in a special solution of known pH value. The Asymmetry Control is then adjusted so that the pH value of the solution is properly indicated either on the standard scale or on the expanded scale, depending on desired accuracy.

These special solutions, known as buffer solutions, are available at exact pH values for precise standardization. Since they resist change in pH value at specific temperatures, their accuracy is dependable. The various Beckman Buffer Solutions and Packaged Buffers are listed in Figure 7.

BECKMAN PART NO.	pH (25°C)	DESCRIPTION
3506	4.01	Buffer solution, in 1-pint polyethylene bottle.
14054	4.01	Packaged buffer. 25 packages and 1-pint, polyethylene bottle. Dissolve contents of each package in 1 pint of distilled water.
22331	6.86	Packaged buffer. 25 packages and 1-pint, polyethylene bottle. Dissolve contents of each package in 1 pint of distilled water.
3501	7.00	Buffer solution, in 1-pint, polyethylene bottle.
3581	7.00	Buffer solution, concentrated, in 1-pint polyethylene bottle. makes 25 pints. Mix with distilled water.
14059	9.18	Packaged buffer. 25 packages and 1-pint, polyethylene bottle. Dissolve contents of each package in 1 pint of distilled water.
3505	10.00	Buffer solution in 1-pint, polyethylene bottle.
22326	12.45	Packaged buffer. 25 packages and 1-pint, polyethylene bottle. Saturate 1 pint of distilled water with the contents of one package.

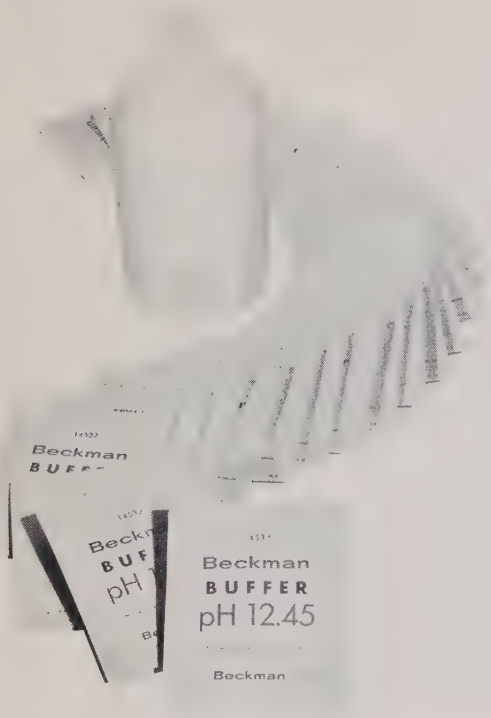
Figure 7. Buffer Solutions and Packaged Buffers

When the instrument is in expanded scale operation, the buffer and test solutions must be within the 2 pH span selected for expansion and they should be as nearly alike in pH as is possible. In addition, when making expanded scale measurements over ranges other than 6 – 8 pH, it is important that the buffer and test solutions be at the same temperature. This is so because zero voltage is at the center of both standard and expanded scales when no scale shifting potential is applied and the scale shifting potential is independent of the temperature compensation potential. The importance of this factor depends upon how far the scale has been shifted. An error of 0.003 pH is introduced per pH unit of scale shift with each degree Centigrade difference in temperature between buffer and test solution. Thus, in the extreme cases (a scale shift from 6 – 8 pH to either 0 – 2 pH or 12 – 14 pH) this error would be 6 x 0.003 or 0.018 pH unit per degree Centigrade difference in temperature between buffer and test solution. In standard scale operation, any temperature difference between buffer and test solutions will generally result in a negligible error when the Temperature Compensator Control is properly set.

It can be seen from the above discussion that in most cases of expanded scale operation, where both buffer and test solution are at room temperature or are thermostatically controlled to identical temperatures, the above problem does not arise.

When the pH range of interest changes and accurate measurements are desired, it will be necessary to standardize the instrument with another buffer having a pH value near the pH of the sample in the new range of interest.

Also, the instrument should be standardized at regular intervals during a long series of measurements, or at least every few days, to account for any changes in electrode asymmetry potential.



5.2 MILLIVOLT SCALE

For millivolt measurements, the Asymmetry Control is used to set the zero position, so that the expanded scale may be shifted to include any 200 millivolt span within a ±1400 millivolt range. On the standard scale, the zero position may be set so that the scale may be shifted to include any 1400 millivolt span within a ±2000 millivolt range. Adjusting the Asymmetry Control varies the voltage to a maximum of ±1300 millivolts, when the mercury battery is fresh.

With no scale shifting potential applied (Asymmetry Control near clockwise limit), the zero position is at the mid-point of the two scales. Under this condition, and with the +MV push-button depressed, the expanded scale includes the 200 millivolt span from −100 to +100 millivolts and the standard scale includes the 1400 millivolt span from −700 to +700 millivolts. Since the scales are always read from left to right, they would read +100 to −100 millivolts and +700 to −700 millivolts, respectively, with the −MV push-button depressed.

When any scale shifting potential is employed, the zero position moves a corresponding amount to the left of mid-point on the scales. For example, when the maximum scale shifting potential of approximately 1300 millivolts is employed (Asymmetry Control at counterclockwise limit), the expanded scale would include the 200 millivolt span between ±1200 and ±1400 millivolts, the polarity depending upon which MV push-button is depressed; that is, zero position is moved off scale 1200 millivolts. If the instrument is in standard scale operation, and the maximum scale shifting potential is employed, the scale includes the 1400 millivolt span between ±600 and ±2000 millivolts — zero position is moved off scale 600 millivolts. When the zero position is shifted off scale, direct measurements, of course, are possible only when a known potential is introduced to indicate how many millivolts zero is shifted.

5.2.1 DIRECT MEASUREMENTS WITH ZERO ON SCALE

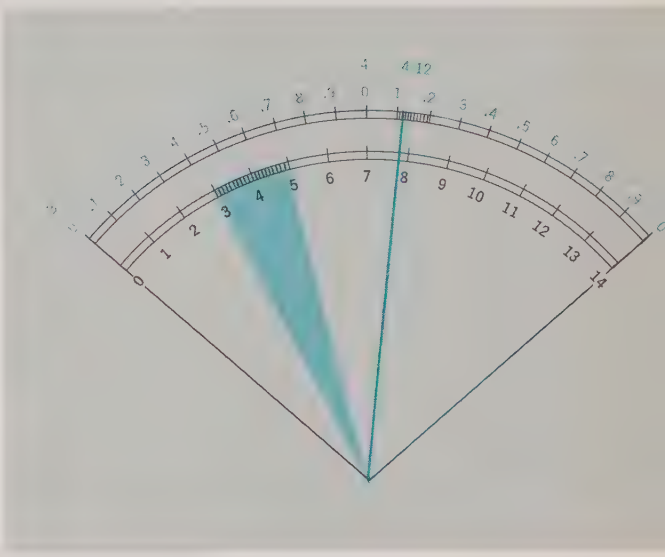
In normal use, it is most convenient to set zero millivolt at the left hand zero position for standard or expanded scale measurements. With this setting of zero, the 0 to 1400 millivolt scale on STD and the 0 to 200 millivolt scale on EXP can be read directly. The sign of the potential applied to the input measured against the REFERENCE is shown by the +MV or −MV push-button.

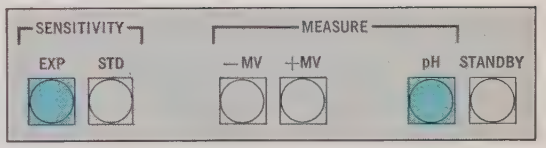
To set zero millivolt at the left hand zero position, a 700 Terminal Connector should be inserted into the INPUT receptacle and a 8980 Shorting Strap connected between the 700 Terminal Connector and the REFERENCE terminal. Push down the STD or EXP button and the +MV or −MV button, depending upon which scale is to be used. Adjust the Asymmetry Control to place zero at the left end of the scale — a shift from the center zero of 100 MV on EXP or of 700 MV on STD. Thus, if the zero is set at the left end of the scale on EXP, it will shift to 6 when the STD push-button is depressed. When the electrodes are connected again, measurements may be made utilizing the full calibrated millivolt range of either scale. A typical example of a millivolt measurement on the expanded scale, obtained by using this technique to shift the scale, is shown in Figure 9.

5.2.2 DIRECT MEASUREMENTS WITH ZERO OFF EXPANDED SCALE

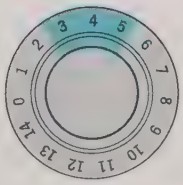
Zero may be shifted off the expanded scale up to 1200 millivolts for measurements in any ±200 millivolt span within a ±1400 millivolt range. To do this, however, it is necessary to introduce a known potential into the instrument through an external source. Furthermore, the accuracy of the source must be at least comparable to the accuracy expected of the instrument in expanded scale operation. An accurate and commonly available potential source is a student's potentiometer, but a standard cell, an appropriate regulated power supply or voltmeter also may be employed.

If this is an adjustable known source, adjust it to the millivolt setting which is the approximate value of the sample. It is convenient if the center zero is designated as a 100 millivolt multiple near to the value of the potential introduced. With the instrument in expanded scale operation, turn the Asymmetry Control until the meter reading agrees with the known potential. Disconnect the known potential source and connect the potential to be measured. Then read the scale in terms of the 100 millivolt values that have been assigned to the three "zero" points on the expanded scale. For example, if a 1.019 volt (1019 millivolts) standard cell is used as a reference and it is desired to measure a potential of around 1.17 volts (1170 millivolts), the range assigned to the expanded scale would be 1000 millivolts to 1200 millivolts. With the standard cell connected, the Asymmetry Control should be turned until .19 is read on the left half of the expanded scale. Then, if the meter were to read .63 on the right-hand half of the scale, with the electrodes connected and immersed in the test solution, the reading would be 1100 millivolts + 63 millivolts = 1163 millivolts. This example of a millivolt reading on the expanded scale, obtained by using an external potential source to calibrate the shift of the scale, is shown in Figure 10.



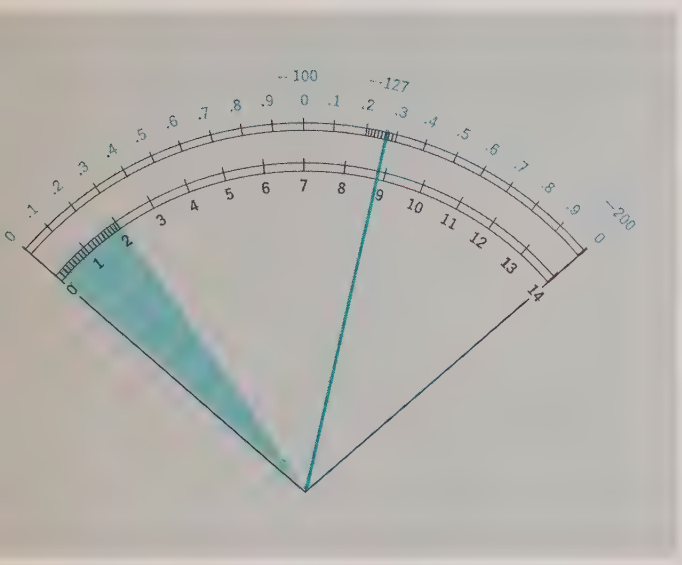


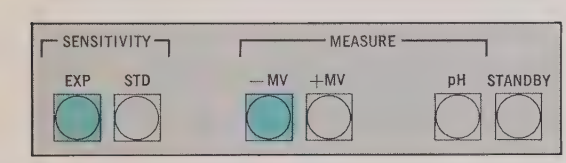
PUSH-BUTTON SETTINGS



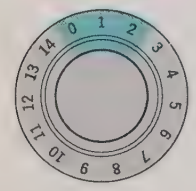
RANGE INDICATOR SETTING

Figure 8. Sample pH Reading on Expanded Scale



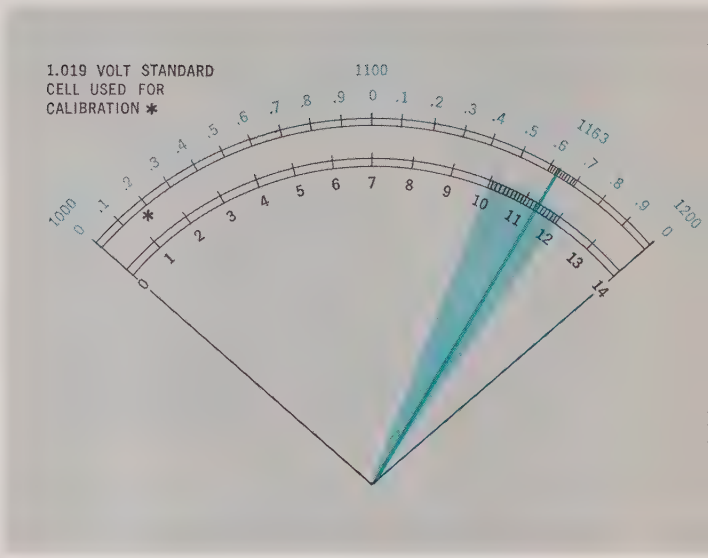


PUSH-BUTTON SETTINGS

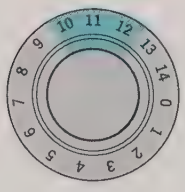


RANGE INDICATOR SETTING

Figure 9. Sample Millivolt Reading with Zero on Scale



PUSH-BUTTON SETTINGS



RANGE INDICATOR SETTING

Figure 10. Sample Millivolt Reading with Zero off Scale

Before accurate pH measurements can be made with the Expanded Scale pH Meter, it must be connected to an a.c. power line and standardized as instructed in Section 5.1. In environments with high relative humidity, leave the a.c. power connected even when the instrument is idle. The following procedures for standardization and pH measurement assume that temperature compensation is made manually (Thermo-Compensator Switch on MAN). If the instrument is equipped with a Thermo-Compensator (Thermo-Compensator Switch on AUTO), the procedure is the same except that references to settings of the Temperature Compensator Control may be disregarded.

NOTE

When taking a meter reading, always observe the needle so that it covers its own reflection in the scale mirror; otherwise, parallax will cause an inaccurate reading.

6.1 STANDARDIZATION PROCEDURE

1. Depress the STANDBY push-button.
2. Pour a buffer solution, with a pH value as close as possible to the pH value of the sample which is to be analyzed, into a small beaker to a depth of about one inch.
3. Slide down the sleeve covering the filling hole of the reference electrode. Check to see that the electrolyte solution in the electrode is at a sufficiently high level and that the liquid junction is flowing satisfactorily. For maximum stability, a new glass electrode must be soaked for several hours before use. Rinse the electrodes and a laboratory thermometer in distilled water and wipe off excess water with a laboratory tissue.
4. Measure the temperature of the buffer solution with the thermometer, set the Temperature Compensator Control at that temperature, and turn the Thermo-Compensator Switch to MAN.
5. Immerse the tips of the electrodes in the buffer solution by positioning the electrode clip on the support rod.
6. Depress the pH push-button and either the EXP or STD push-buttons. Allow about a minute for the reading to stabilize (if a Thermo-Compensator is used, it may take up to 5 minutes to stabilize).
7. Adjust the Asymmetry Control until the meter reading corresponds with the pH of the buffer at the temperature measured in Step 4. A temperature correction table is on each Beckman Buffer Solution container. If the instrument is being standardized in expanded scale operation, designate the three zero positions as the appropriate whole numbers that will also include the pH value of the test solution.
8. Set the Range Indicator at the 2 pH span included on the expanded scale (refer to Figure 8).
9. Depress the STANDBY push-button.
10. Remove the electrodes from the buffer solution, rinse them in distilled water, and wipe away the excess with a laboratory tissue. Proceed with pH measurement as described in the following paragraph.

6.2 STANDARD SCALE pH MEASUREMENT

1. Standardize the instrument with the proper buffer solution as described in Paragraph 6.1.
2. Depress the STANDBY push-button.
3. Rinse the thermometer and the electrodes in distilled water and wipe off the excess water with a laboratory tissue.
4. Immerse the tips of the thermometer and the electrodes in the test solution.
5. Set the Temperature Compensator Control at the temperature of the test solution.
6. Depress the STD push-button.
7. Depress the pH push-button.
8. Read the pH value of the sample on the standard scale.

6.3 EXPANDED SCALE pH MEASUREMENT

1. Standardize the instrument with the proper buffer solution.
2. Depress the STANDBY push-button.
3. Rinse the thermometer and the electrodes in distilled water and wipe off the excess water with a laboratory tissue.
4. Immerse the tips of the thermometer and the electrodes in the test solution.
5. Set the Temperature Compensator Control at the temperature of the test solution. If the expanded scale is set to other than the 6 to 8 pH range, the test solution temperature must be the same as the temperature of the buffer used to standardize the instrument.
6. Depress the EXP push-button.
7. Depress the pH push-button.
8. Read the pH value of the sample on the expanded scale. Refer to the Range Indicator setting, established in the standardization procedure, and interpret the reading as shown in Figure 8.

Section 7. Potential Measurement

The Expanded Scale pH Meter may be used for potential measurements in the range from −2000 to +2000 millivolts. The standard scale range is extended beyond the ±1400 millivolt range in which the scale is graduated by placing zero off scale up to 600 millivolts. However, the expanded scale may be utilized for any ±200 millivolt span only in the ±1400 mililvolt range. The millivolt scale shifting procedures are discussed in Paragraph 5.2.

Equip the instrument with the correct electrodes for the particular measurement. Prepare the electrodes according to the instructions accompanying them.

NOTE

When taking a meter reading, always observe the needle so that it covers its own reflection in the scale mirror; otherwise, parallax will cause an inaccurate reading.

7.1 STANDARD SCALE

1. Depress the STANDBY push-button.
2. Plug a 700 Terminal Connector into the glass electrode (INPUT) terminal and connect an 8980 Shorting Strap between the terminal connector and the reference electrode terminal.
3. Depress the STD push-button.
4. Depress the appropriate MV push-button.
5. Turn the Asymmetry Control until the meter needle is at zero.
6. Depress the STANDBY push-button.
7. Connect the electrodes, rinse with distilled water and wipe off the excess water with a laboratory tissue.
8. Immerse the tips of the electrodes in the test solution.
9. Depress the appropriate MV push-button.
10. Read the potential on the standard scale.

If the measurement requires a greater range of scale refer to Paragraph 5.2 for scale shifting procedures. The pH meter is capable of measuring potentials up to 2000 millivolts.

7.2 EXPANDED SCALE

1. Depress the STANDBY push-button.

2. Plug a 700 Terminal Connector into the glass electrode (INPUT) terminal and connect an 8980 Shorting Strap between the terminal connector and the reference electrode terminal.
3. Depress the EXP push-button.
4. Depress the appropriate MV push-button.
5. Turn the Asymmetry Control until the meter needle is at left-hand zero.
6. Depress the STANDBY push-button.
7. Connect the electrodes, rinse with distilled water and wipe off the excess water with a laboratory tissue.
8. Immerse the tips of the electrodes in the test solution.
9. Depress the appropriate MV push-button.
10. Read the potential on the expanded scale. (See Figure 9.)

If the measurement is not in the ±200 millivolt range, the scale can be shifted to include any 200 millivolt span in the ±1400 millivolt range by using the scale shifting procedures described in Paragraph 5.2. Refer to the Range Indicator setting and interpret the reading as shown in Figure 10.

Section 8. Titrations

The Expanded Scale pH meter may be utilized for the determination of titration end-points for potentiometric titrations and polarization titrations, such as Karl Fischer, Bromine Number and similar reactions. Employment of this instrument eliminates the necessity for evaluating color changes at the end-point of a reaction, and makes possible determinations in dark or colored solutions.

For potentiometric titrations, select the proper electrode for the measurements required and read the pH or millivolt scale as described in Section 6 or 7 as the titration proceeds.

For polarization titrations mentioned previously, a polarizing current of about 10 microamperes is available at the terminal board at the rear of the instrument. To apply this polarizing current to the electrodes, proceed as follows.

Figure 11. Performing Titrations with the Expanded Scale pH Meter

8.1 PROCEDURE

1. Disconnect the glass electrode from the glass electrode (INPUT) terminal on the terminal board.
2. Insert a Beckman 700 Terminal Connector into the INPUT terminal to adapt this terminal for phone-tipped leads.
3. Plug the phone-tip end of a Beckman 5083 Polarizing Jumper into the polarizing current terminal on the instrument terminal board.
4. Connect a Beckman Metallic Electrode to the 700 Terminal Connector and fasten the spring clip of the polarizing jumper onto the protruding portion of the electrode phone-tip lead end.
5. Connect a second Beckman Metallic Electrode to the reference terminal.
6. Proceed with titration as in the procedure outlined in Section 7 for millivolt measurements.

When the instrument registers a sudden permanent change, the titration endpoint has been reached. The endpoint for a direct Karl Fischer or Bromine Number is indicated by a sudden decrease in the reading to about zero potential. For a back titration, the end point is indicated by a sudden permanent increase in potential. The amount of sudden increase or decrease in potential will, of course, depend upon the ion concentration (electrical resistance) of the test solution.

For micro-titration studies where the end-points must be determined accurately, the expanded scale on the instrument should be utilized.

Detailed information on titrations, necessary equipment and extensive bibliographies are included in the following Applications Data Sheets available from Beckman Instruments, Inc.

pH-79-Ml *pH Meters for Rapid, Reproducible Titrations*

Z-80-Ml *Easier, Quicker Moisture Determinations (Karl Fischer Titration Method)*

pH-83-Ml *Nonaqueous Titrations*

The various types of Beckman electrodes needed for special applications are cataloged in *Beckman Bulletin 86.*

Section 9. Applications

Although the Expanded Scale pH Meter may be used for any standard pH or electrochemical potential measurement, it is ideally suited for applications where very small changes in pH or potential must be detected. As a millivoltmeter, the high impedance input of the instrument minimizes electrode polarization effects so that precise potential measurements can be made directly. The following paragraphs list briefly a few of the applications where the expanded pH and millivolt scales of the instrument have been used advantageously.

The instrument is particularly valuable for studies in the fields of medicine and biology. In these fields, preliminary research indicates the desirability of determining pH of body fluids with greater accuracy than is possible with standard laboratory pH meters. For example, certain cardio-pulmonary operations require that the hydrogen ion balance of the blood stream be maintained at a constant level during operative procedures — the Expanded Scale pH Meter may be used to detect any significant change in this level.

Many titrations that cannot be detected by standard laboratory pH meters may be performed satisfactorily with the Expanded Scale pH Meter. This permits the determination of titration end-points at which the potential changes only slightly, such as in the titration of very dilute solutions, of weak bases in glacial acetic acid solvent or of a series of complexing agents in the presence of one another.

The expanded pH and millivolt scales may be used to great advantage for studies of colloidal systems. Use of the instrument permits more accurate pH control of gels, jams, jellies, and drilling muds.

Other applications include the study of electrodes and electrode kinetics, standardization of electrodes and buffers, measurement of activity coefficients of solutes and potentiometric determinations of trace amounts of ions, such as chloride from pesticide residues or sodium and potassium in water.

Section 10. Circuit Operation

The Expanded Scale pH Meter provides an amplifier and associated circuitry to connect pH electrodes to an indicating meter and recorder. The electrodes appear as voltage generators in series with a very large resistance, the generator having a voltage of the order of .5V with hundreds of megohms internal resistance. Without causing errors due to an IR drop across the generator resistor, the instrument must convert this voltage to deflection of a meter needle, or an output for a recorder. The amplifier accomplishes this by using negative feedback. Figure 12A shows a simplified diagram of the meter circuitry.

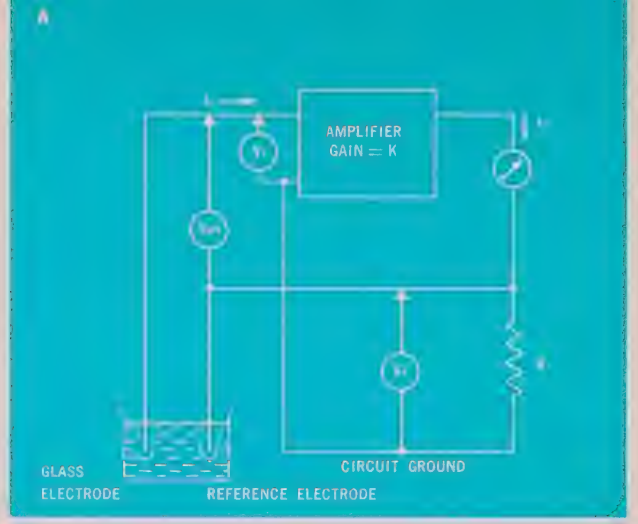
The glass electrode is connected to the amplifier input while the reference electrode is connected to the amplifier output, and the electrical path is completed through the conductivity of the solution between the electrodes. Because of this connection, the voltage (V_i) applied to the amplifier input is the difference between the amplifier output voltage and the algebraic sum of the potentials of the electrodes. If the amplifier gain is large (greater than 1000), V_i will be small (Vo/K) and can be neglected. Since V_i is small, the current required by the input resistance of the amplifier is small. As a result, the resistance presented to the electrodes is

$$\frac{V_{pH}}{I_i} = \frac{V_{pH}}{\frac{V_i}{R_i}} = R_i K.$$

10.1 AMPLIFIER

The amplifier must amplify d.c. signals and must not produce spurious signals of its own such as d.c. drift. It does this by modulating the input voltage to produce an a.c. signal, which is then amplified and demodulated to reproduce a d.c. signal. This is shown diagrammatically in Figure 13.

The input voltage is passed through a low pass filter to attenuate any a.c. signals on the input, provide a moderately high impedance to the input during switching transients and provide a low a.c. impedance for the modulator.



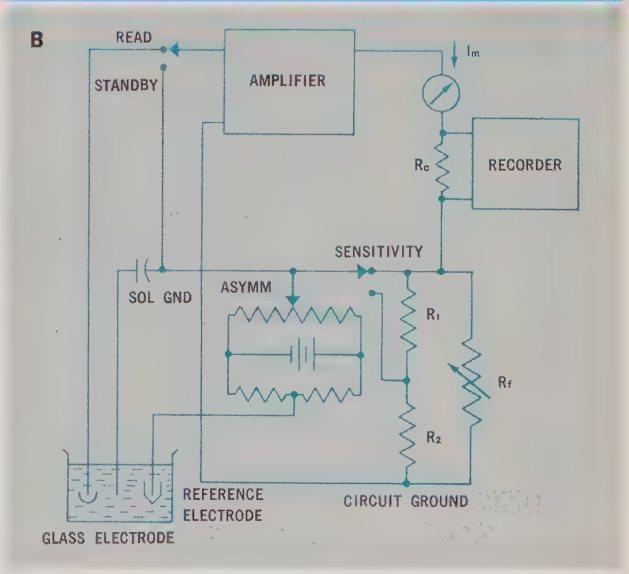


Figure 12. Simplified Meter Circuit

The modulator is a mechanical switch alternately connecting the amplifier input between ground and the input voltage, thus producing a square wave with magnitude equalling the input voltage.

The a.c. preamplifier uses an electrometer tube to convert the high impedance voltage signal to a current signal for the a.c. amplifier. These first three blocks are contained in the preamplifier plug-in unit.

The a.c. amplifier is a conventional two-stage transistor amplifier. The first stage uses the Darlington connection to provide a current gain which is approximately the product of the two Betas of the transistors. The second stage provides further gain and the drive necessary for the demodulator.

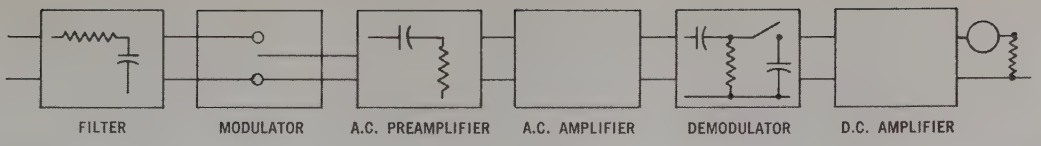


Figure 13. Simplified Amplifier Circuit

The demodulator is the electrical equivalent of a switch. In synchronism with the modulator switch, it connects the output of the a.c. amplifier to a capacitor. When the switch is open, the voltage across the capacitor remains constant, but when the switch is closed the voltage on the capacitor is equal to the amplifier output. Consequently, the peak-to-peak value of the amplified a.c. voltage is converted to a d.c. voltage.

The output voltage of the demodulator is further amplified by the d.c. amplifier which has the ability to drive the output meter, recorder resistor, and feedback resistor network.

10.2 ADAPTING THE AMPLIFIER FOR INSTRUMENT USE

The associated circuitry transforms the amplifier to a useful instrument with calibrated outputs. Figure 12B shows the important elements in simplified form. This diagram, like Figure 12A, shows the electrodes connected between the output and input of the amplifier. In addition, the Asymmetry Control is shown in series with the electrodes. Thus, any voltage that may be produced by the electrodes can be bucked out by the Asymmetry Control so the meter will read the changes of potential from the initial setting.

The switch labeled "Sensitivity" allows the instrument to have two sensitivities. The potential between the arm of this switch and circuit ground remains equal to the sum of the voltages of the Glass Electrode, Reference Electrode and Asymmetry potential. Therefore, the amplifier must increase the meter current when the switch is moved from the upper, less sensitive, position to the lower position so that the new voltage developed across R_f when attenuated by R_1 and R_2 equals the previous voltage. This switching is done by the STD — EXP push-buttons.

The value of R_f is chosen so that when a particular current I_m flows, the desired potential will be developed across R_f. Because the voltage equivalent to pH depends upon temperature, the meter can be made to read the correct pH value by adjusting R_f. This is done by the temperature potentiometer or it may be done by a thermo-compensator, a temperature sensitive resistor which when connected in place of R_f and immersed in solution produces the desired resistance and automatically controls the instrument gain. Thirdly, a fixed resistance can be connected in place of R_f so that the instrument will indicate millivolts. This switching is accomplished by the pH, +MV, −MV buttons, and by the Thermo-Compensator Switch on the rear of the instrument.

A voltage output can be developed for a recorder, by passing the meter current I_m through a suitable resistor to produce the desired voltage. A current output can be obtained by passing a portion or all of I_m through the recorder.

A read-standby switch disconnects the amplifier input from the electrodes and connects it to the amplifier output. Thus the amplifier feedback loop remains closed keeping it in standby condition. At the same time the electrodes will not be accidentally polarized during their placement in the solution. The amplifier will not be damaged by voltages many times normal and is like a vacuum tube voltmeter (VTVM) in this respect.

Extraneous signals, mainly 60 cps, can cause spurious readings. If the solution does not have low impedance to circuit ground, an extraneous signal can develop a potential at the input to the amplifier. Although the input filter attenuates a.c. voltages, any 60 cps appearing at the filter output passes through the modulator and then cannot be distinguished from legitimate signals. Consequently, it will appear on the meter as a pH indication. This can be minimized by connecting the SOLUTION GND terminal to the solution, thus providing a low impedance path for the spurious signal without shorting the pH potentials in the reference electrode.

Shielded leads must be used between the glass electrode and the input terminals to shield this line from spurious signals. When very long leads are used with high impedance electrodes, a delay is inserted in the amplifier feedback loop which can cause underdamped response or oscillation.

Section 11.
Service and Maintenance

The Expanded Scale pH Meter case and electronics layout are designed for simplicity and ease in the service and maintenance of the instrument. Data contained in this section aid the operator in detecting malfunctions of the instrument and in making the necessary correction, either by adjustment or by replacement of components. The nature of instrument failure may be determined quickly by referral to the trouble shooting charts (Figure 14). As additional aids, the pictorial wiring diagram (Figure 15) and the schematic wiring diagram (Figure 16) will help to pinpoint possible circuit trouble. Instrument circuit operation is described in the preceding section. Although some of the service and maintenance may be accomplished by the operator, repairs involving major circuit changes should be made only by a trained technician. A competent staff of Beckman Dealer Service Representatives is maintained to provide customers with any assistance necessary in servicing the instrument. Most of the electronic components are mounted on the amplifier and power supply assemblies. Both of these assemblies have printed circuit boards that require thorough testing to locate a faulty component. It may be advantageous for the operator to keep a spare assembly of each readily available. The faulty assembly may then be repaired when convenient, or repaired through the facilities of a Beckman Dealer Service Representative, so that the instrument need not be out of operation while components of the assemblies are being tested.

Trouble Shooting Charts

USE OF TROUBLE SHOOTING CHARTS

Meter must read 7 pH when a.c. power is disconnected. Turn Meter Adjustment Control to correct reading, if necessary.

If recorder is connected to instrument, temporarily disconnect it.

To pass current through meter circuit, the recorder terminals on pH meter must be connected together by a resistor (less than 2000 ohms) or by a shorting strap. Connections may be made inside or outside of case. It also is necessary for Thermo-Compensator Switch to be set at MAN or for a thermo-compensator to be connected to corresponding rear panel terminals.

Electrodes must be connected properly and immersed in sample or buffer solution. The a.c. power must be connected.

Press combination of push-buttons which permits trouble to be present. Then, in turn, press STANDBY, +MV, −MV, and pH push-buttons and, at each setting, attempt to bring meter reading on scale by turning Asymmetry Control. Look for trouble at each setting.

If trouble exists only in STANDBY operation, check STANDBY switching circuit.

If trouble exists on one or two measuring ranges (+MV, −MV, and pH), but not on all three, then check those switching circuits which are employed only when trouble exists.

IF TROUBLE EXISTS ON ALL THREE MEASURING RANGES

(+MV, −MV, and pH): Read note above. Leave pH push-button pressed and turn the Asymmetry Control. Select symptom on following page which most nearly describes trouble and follow corresponding directions.

Figure 14. Trouble-Shooting Charts

SYMPTOMS

METER READS OFF SCALE:
Refer to Chart A.

METER READING IS NOISY OR ERRATIC:
Refer to Chart B.

METER READS ON SCALE, BUT DOES NOT RESPOND TO CHANGES IN pH:
Refer to Chart C.

METER GIVES INACCURATE READING, BUT OTHERWISE OPERATES PROPERLY:
Refer to Chart D.

METER POINTER IS UNDERDAMPED AND/OR VERY SLOW TO RESPOND TO pH CHANGES (USUALLY MORE NOTICEABLE ON THE EXP. RANGE):
Refer to Chart E.

METER POINTER OSCILLATES:
Refer to Chart F.

METER ACCURACY IS GOOD, BUT ELECTRODES GIVE FAULTY READINGS:
Refer to Chart G.

ASYMMETRY CONTROL HAS INSUFFICIENT RANGE OR FAILS TO OPERATE:
Replace mercury battery.

METER READS OFF SCALE. Note direction for later use:
Disconnect electrodes. Insert 700 Terminal Connector into INPUT receptacle and connect to REFERENCE receptacle with 6880 Shorting Strap. Then try to bring meter reading on scale by turning Asymmetry Control.

METER READS ON SCALE:
Check electrode circuit and electrodes. Perhaps reference electrode needs refilling or tip has become clogged.

METER READS OFF SCALE:
Press STANDBY push-button. Meter should read 7 pH.

METER READS 7 pH:
Check wiring from REFERENCE receptacle, through Asymmetry Control circuit, to push-button switch. If switch contacts are dirty, clean by using a soft brush and suitable non-toxic, non-corrosive solvent. Also check wiring from INPUT receptacle to push-button switch.

METER READS OFF SCALE AT 0 pH END:
(It is not likely that reading will be on scale, unless it reads 7 pH):
Short circuit R27, collector load resistor for transistor Q3, by connecting clip-lead from collector of Q3 to accessible end of R27. Slowly turn demodulator balance control (R32, on power supply) to make meter read near center of scale.

METER READS OFF SCALE AT 14 pH END
Connect clip-lead from base of transistor Q4, to junction of R7– R15 +18V. Then observe meter reading.

METER STILL READS OFF SCALE AT 14 pH END:
Replace transistor Q4.

METER READS OFF SCALE AT OPPOSITE END
Short circuit R27, collector load resistor for transistor Q3, by connecting clip-lead from collector of Q3 to accessible end of R27. Slowly turn demodulator balance control (R32, on power supply) to make meter read near center of scale.

CANNOT ADJUST METER READING:
Check demodulator output (by using d.c. voltmeter connected from base of transistor Q4 to accessible end of resistor R24) while turning demodulator balance control R32. Should be able to obtain positive and negative d.c. potentials of about one volt. Leave control set so potential is nearly zero.

METER READS NEAR CENTER:
Remove short circuit from R27. Remove preamplifier signal input lead from receptacle X5. Connect lead from receptacle X5 to positive (red wire) meter terminal. Meter should read 7 pH.

POTENTIAL NOT CORRECT:
Check potentiometer R32 and other parts of demodulator circuit. If meter was off scale at 0 pH, look for faulty diode CR1. If it was off scale at 14 pH, look for faulty diode CR2. Test by connecting d.c. voltmeter across diode. Reading lower than one volt indicates diode is bad.

POTENTIAL O.K. AND METER OFF SCALE AT 14 pH:
Replace capacitor C10.

POTENTIAL O.K. AND METER OFF SCALE AT 0 pH:
Connect 22,000 ohm resistor from base of transistor Q4 to accessible end of R27 (–6V). Measure d.c. potential from base of Q4 to junction of R7 — R15 (+18V).

METER DOES NOT READ 7 pH:
Slowly turn demodulator balance control, R32, in effort to make meter read on scale.

METER READS 7 pH:
Check input circuit contacts at pushbutton switch. If STANDBY switch fails to operate properly, bend contact leaves to make firm connection, taking care to avoid contaminating plastic insulating spacers. Also check wiring from switch to preamplifier receptacle, X5, or look for short circuit in feedback path associated with resistors R6, R17, R9, and potentiometer R10.

POTENTIAL NOT ZERO:
Replace transistor Q4.

POTENTIAL ZERO:
Replace capacitor C9.

METER READS OFF SCALE:
Connect clip-lead across R15, plate load resistor of tube V1. Meter should read on scale. Turn demodulator balance control, R32, if necessary.

METER READS ON SCALE:
Temporarily connect 2 MEG resistor to end of R15 (39K) which connects to pin 2 of preamplifier. Connect clip-lead from free end of 2 MEG resistor to one of red leads of transformer T1. Meter should read off scale. Then connect free end of 2 MEG resistor to other red lead of transformer T1 (again using clip-lead). Meter should read off scale at opposite end. (Disconnect 2 MEG resistor and clip-lead.)

METER READS ON SCALE:
Replace chopper or preamplifier. If chopper drive coil leads could have become reversed in polarity, reverse them. Remove clip lead from R15. Meter should read near 7 pH.

METER READS OFF SCALE:
Look for source of 60-cycle a.c. pick-up in amplifier. After repairing, remove clip lead from R15.

METER DID NOT RESPOND:
Find amplifier fault by comparing circuit potentials with circuit diagram. Remove transistor associated with an incorrect potential and observe potential again. If potential is correct, replace transistor. If potential is still incorrect, do same thing with related bypass or coupling capacitor. Then check related resistors. If trouble on printed-circuit board cannot be located by conventional measurement or by probing with insulated tool, check for faulty soldering or use magnifying glass to look for small cracks or breaks in etched conductors. Bridge across any breaks, using a relatively cool soldering iron tip.

METER RESPONDED AS DESCRIBED:
Test chopper by using ohmmeter set on X1000 range, as follows:
Remove chopper and connect ohmmeter to pins 2 and 3. Fit chopper drive coil loosely over neck of chopper and apply power. Ohmmeter should read near mid-scale, indicating that contacts open about half of the time. Repeat test, connecting ohmmeter to pins 3 and 4. Meter should again read near mid-scale.

READINGS ARE CORRECT:
Replace preamplifier.

INCORRECT READING:
Replace chopper. However, first check drive coil, if not sure it operated properly in above test. Do this by connecting a.c. voltmeter in series with one of coil leads. Voltmeter should read near 6 volts.

AFTER ELIMINATING TROUBLE:
Remove X5-to-meter connection and plug in preamplifier input lead. Reset demodulator balance control, R32, as follows:
Disconnect amplifier-to-power supply cable at amplifier and connect volt-ohm-milliammeter (20,000 ohms per volt is preferred) between pins 3 and 6 of disconnected plug. Turn demodulator balance control to give zero reading on most sensitive d.c. current range of VOM meter. Then check reverse currents of demodulator diodes by switching to lowest d.c. voltage range of VOM meter. Reading greater than two or three smallest scale divisions (depending on make and model of VOM meter) indicates that at least one diode should be replaced, after which preceding adjustment must be made again. If both readings (current and voltage) are satisfactory, adjustment is correct. Disconnect VOM meter and plug in cable connector.

CHART B

METER READING NOISY OR ERRATIC:
Press STANDBY push-button.

READING BECOMES STABLE:
Disconnect electrodes, insert 700 Terminal Connector into INPUT receptacle and connect to REFERENCE receptacle with 8490 Shorting Strap. Press pH push-button and observe meter reading.

READING CONTINUES NOISY:
Tap preamplifier lightly and observe meter reading.

READING REMAINS STABLE:
Check electrode circuit and electrodes. See if reference electrode needs refilling or if tip is clogged. Check solution grounding. See Page 3.4.)

READING BECOMES NOISY OR ERRATIC AGAIN:
Remove battery from rear panel

PREAMPLIFIER MICROPHONIC:
Replace it.

ELECTRODE CIRCUIT AND ELECTRODES ARE GOOD:
Press STANDBY push-button, disconnect 700 Terminal Connector and 8490 Shorting Strap, and plug Beckman 71968 1000 megohm Resistor into input receptacle. Insert resistor lead into reference receptacle. Press pH push-button and observe meter reading.

READING BECOMES STABLE:
Put in new battery, after making sure that battery holder contacts are free of corrosion.

READING IS STILL NOISY OR ERRATIC:
Look for trouble in asymmetry control circuit.

TROUBLE IS NOT PRESENT:
Instrument is operating properly. Recheck electrode circuit.

TROUBLE PERSISTS:
Replace preamplifier and/or chopper. Also check insulation of input circuit wiring.

POTENTIAL IS HIGH:
Measure potential from top of R40 (−6V) to collector of transistor Q7.

POTENTIAL IS ZERO:
Replace transistor Q7.

POTENTIAL IS GREATER THAN .1 VOLT:
Look for trouble in transistor Q5 and Zener diode CR5 circuit. (Some of "Potential is Low *" checks may prove helpful here, too.)

NOISE INCREASES:
Look for noise in amplifier. Do not replace components hit-and-miss. Instead, remove 100 ohm resistor and find fault by lowering gain at successive points in amplifier, as above, remembering that with negative feedback connected, noise at meter will become greater when gain ahead of noise source is lowered. As gain following noise source is lowered, noise at meter will remain same or will diminish.

NOISE SAME OR LESS:
Remove 100 ohm resistor and remove preamplifier input lead from receptacle X5. Then, connect lead from receptacle X5 to positive terminal (red wire) of meter.

NOISE DISAPPEARS:
Remove test lead from X5-to-meter. Check input circuit contacts at push-button switch, and wiring from switch to preamplifier receptacle X5. If STANDBY switch fails to operate properly, bend contact leaves to make firm connection, taking care to avoid contamination of plastic insulating spacers.

NOISE PERSISTS:
Replace chopper, preamplifier and amplifier, in that order, checking noise after replacing each unit. When bad unit is found, put back original units to see if they are good.
NOTE: Neither chopper nor preamplifier can be repaired. In repairing other units, if fault cannot be located by conventional measurement or by probing with insulated tool, check for faulty soldering. Use magnifying lens to look for small cracks or breaks in etched conductors. Bridge across any breaks with solder using relatively cool soldering tip.

ALL UNITS APPEAR TO BE GOOD:
Push cable plugs firmly into their sockets to ensure good contact. Flex cables at joints to check for broken wires or poorly soldered connections.

CHART B CONTINUED

PREAMPLIFIER NOT MICROPHONIC:
Connect a .005 microfarad capacitor in series with one lead of a.c. voltmeter. Connect other voltmeter lead to accessible end of transistor Q3 collector load resistor (R27) and connect free end of .005 microfarad capacitor to collector of Q3. Voltmeter reading will be less than one volt, unless parasitic oscillation is present in Q1, Q2, and Q3 circuits.

READING IS ONE VOLT OR MORE:
Replace capacitor C15. If oscillation occurs as result of having replaced transistors Q1, Q2, or Q3, it may be due to exceedingly high current gain (beta) in any one of these transistors. Try other transistors, selected at random, until suitable combination is found. Merely changing capacitor C15 will not correct situation.

READING IS LESS THAN ONE VOLT:
Connect clip lead across R15 (39K), plate load resistor of tube V1. Obtain 10 or 20 microfarad (no greater) electrolytic test capacitor, rated at 50 volts or more. Equip it with clip leads. To prevent subsequent damage to transistor, temporarily connect test capacitor positive terminal through d.c. milliameter to junction of resistors R7 — R15 1200 ohms and 39K on the amplifier board (+18V), and connect test capacitor negative lead to accessible end of resistor R27 (−6V, on amplifier board. When test capacitor leakage current becomes less than one milliampere, remove milliammeter from test circuit and test power supply for noise as follows:
a. With positive capacitor lead connected to +18V point, shift negative capacitor lead to base of transistor Q1 and observe noise in pH meter reading.
b. Shift negative capacitor lead back to −6V point, shift positive lead to base of transistor Q1, and again observe meter noise. Power supply is good if noise is same both ways.
c. End test by disconnecting short circuit from R15 and by disconnecting test capacitor.

SAME NOISE EACH WAY:
Look again at original noise. Then, temporarily connect 100 ohm resistor across resistor R15 (39K) plate load of tube V1. After switching transient dies out, observe noise.

MORE NOISE WITH PROCEDURE b:
Measure regulated potential between top of R40 (−6V) and end of R45 which is nearest to center of board (+18V). Potential should be 24 volts.

POTENTIAL IS 24 VOLTS:
Check for noisy resistor in base circuit of transistor Q5 by replacing resistors one at a time. When searching for power supply noise, it is helpful to set up connections in step b portion of READING IS LESS THAN ONE VOLT above, so that noise will show better on meter.

POTENTIAL IS LOW: *
Measure a.c. ripple potential at collector of transistor Q7, relative to top of resistor R40 (−6V). Use "output" range of a volt-ohm-milliameter if an oscilloscope is not available. Ripple should be about .2 volts RMS, or less.

RESISTORS ARE GOOD:
Replace transistor Q5 and/or diode CR5.

RIPPLE IS HIGH:
Replace capacitor C13.

RIPPLE IS GOOD:
Check power line a.c. potential. It should be 115V ±10% or 230V ±10%.

POWER LINE IS INCORRECT:
Instrument is not at fault. Try to obtain higher power line potential, perhaps by using appropriate voltage step-up transformer.

POWER LINE IS GOOD:
Measure d.c. potential across capacitor C13. It should be about 34 volts, or higher, at normal power line potential.

POTENTIAL IS GOOD:
Measure d.c. potential across diode CR5. It should be 13 volts

POTENTIAL IS LOW:
Check rectifiers CR3 and CR4.

POTENTIAL IS INCORRECT:
Replace diode CR5.

POTENTIAL IS GOOD:
Disconnect instrument from power line. Temporarily disconnect plug P3 from power supply and measure resistance of R41 without removing it from circuit. Take readings with ohmmeter leads first in one polarity, then in other. Highest reading should be 620 ohms. (Plug in P3 again.)

RESISTANCE IS INCORRECT:
Replace R41, but when old R41 is free from circuit, measure it again just to be sure that circuit had not affected previous reading.

RESISTANCE IS GOOD:
Connect power again and momentarily connect 2000 ohm resistor across resistor R45 and observe change of potential between top of R40 (−6V) and end of R45 which is nearest center of board (+18V). Potential should increase about 4 volts.

POTENTIAL CHANGES CORRECTLY:
Ratio of divider resistors at base of Q5 is incorrect. Select new resistor R45 to give 24 volts across +18V and −6V points.

NO CHANGE OF POTENTIAL:
Replace transistor Q5, or look for open resistor R38 in collector circuit of Q5.

Q5 AND R38 ARE GOOD:
Measure d.c. potential from collector to-emitter of transistor Q6. It should be at least one volt.

POTENTIAL INCORRECT:
Replace Q5, or check resistors R35 and R36.

CHART C

METER READS ON SCALE, BUT DOES NOT RESPOND TO CHANGES IN pH:

Disconnect electrodes and put 700 Terminal Connector into INPUT receptacle. Then, touch end of 700 Terminal Connector with finger and observe meter.

NO METER RESPONSE:

Check fuse F1.

METER RESPONDS:

Connect 8980 Shorting Strap between INPUT (700 Terminal Connector) and REFERENCE receptacles and check meter response to rotation of Asymmetry Control.

POOR RESPONSE:

Refer to Chart E.

GOOD RESPONSE:

Check electrodes and electrode circuit.

ELECTRODE CIRCUIT AND ELECTRODES ARE GOOD:

Press STANDBY push-button, disconnect 700 Terminal Connector and 8980 Shorting Strap, and plug a Beckman 71968 (1000 megohm) Resistor into the INPUT receptacle. Insert the resistor lead into the REFERENCE receptacle. Press pH push-button. Turn Asymmetry Control and observe meter response.

METER RESPONSE GOOD:

Instrument is operating properly. Recheck electrode circuit.

METER DOES NOT RESPOND:

Replace preamplifier and/or chopper. Also check insulation of input circuit wiring.

FUSE IS BLOWN:

Replace fuse. (Fuses sometimes fatigue; blown fuse does not always indicate other trouble.)

FUSE IS GOOD:

Check to see if a.c. power line potential appears across terminals of plug P5.

FUSE BLOWS AGAIN:

Disconnect a.c. power and replace fuse again. Repair power supply. Look for defective transformer T1 shorted rectifier CR3 or CR4, shorted filter capacitor C13 or other short circuit from +18V point to −6V point. Diode CR5 and transistors Q5 and Q7 may each be short circuited internally.

POTENTIAL ZERO:

Check power line circuit.

POTENTIAL SAME AS POWER LINE:

Check regulated d.c. potential of power supply: measure between top of resistor R40 (−6V end of resistor R45 which is nearest to center of power supply board. Potential should be 24 volts.

POTENTIAL 24 VOLTS:

Find trouble in amplifier by comparing d.c. potential readings with circuit diagram. Remove transistor associated with incorrect potential and observe potential again. If potential is correct, replace transistor. If not, do same with related bypass or coupling capacitor, then check related resistors. Here is an additional check: If just one of transistors Q1 and Q2 is bad, instrument should still operate when faulty transistor is removed and connection is made from its base connection point to its emitter connection point. If trouble on printed circuit board cannot be located by conventional measurement or by probing with insulated tool, check for faulty soldering or use magnifying glass to look for small cracks or breaks in etched conductors. Bridge across any breaks, using relatively cool soldering iron tip. Also, check for disconnected amplifier cable plug.

POTENTIAL NOT 24 VOLTS:

Find trouble in power supply. Look for open transistor Q7. Portion of Chart B starting with "Potentiometer Is Low" may be helpful.

AMPLIFIER AND ALL CABLE CONNECTIONS GOOD

Measure d.c. potential from collector of transistor Q4 to circuit ground (0V end of resistor R19). If potential of 0.1 volt or more exists and yet meter reads near to 7 pH, measure d.c. potential from wire to circuit ground at successive points down meter current path in order to locate open circuit or shorted meter. Do not attempt to measure resistance with ohmmeter as it can damage meter.

CHART D

METER GIVES INACCURATE READING, BUT OTHERWISE OPERATES PROPERLY:

Connect clip lead across meter terminals and turn meter mechanical zero adjustor to make meter read exactly 7 pH; then remove clip lead. (When setting mechanical zero control, place case in normal upright position.) Disconnect electrodes, insert 700 Terminal Connector into INPUT receptacle, and connect clip-lead from 700 Terminal Connector to Asymmetry Control clockwise terminal (nearest knob-end of Helipot). Next, press EXP pushbutton, turn Asymmetry Control to make meter read 0 pH, and press STD push-button. Meter should read 6 pH.

METER READS 6 pH BUT IS INACCURATE ON +MV, −MV, OR pH WITH MANUAL TEMPERATURE CONTROL:

Press −MV push-button and turn Asymmetry Control to make meter read −269 millivolts on the 0 to −1400 millivolt scale. Set Temperature Compensator Switch to MAN position. Then press pH push-button. Meter should read 0 pH, ±0.2 pH.

METER READS 6 pH, BUT INACCURATE WHEN USING AUTOMATIC THERMO-COMPENSATOR:

Measure thermo-compensator resistance. Should be 4142 ohms at 25°C and change 14.2 ohms per degree C change.

METER FAILS TO READ 6 pH:

Check scale-expansion feedback resistors, R6 and R17. Also check capacitor C1 for short circuit or partial short circuit.

READING CORRECT:

Check meter to be sure it is properly shunted (−102 μa to +102 μa, full scale).

READING INCORRECT:

Measure resistance of MV feedback resistor, R8. It should be 7100 ohms ±.25%.

R8 NOT 7100 OHMS:

Replace R8.

R8 GOOD:

Re-set manual temperature control knob relative to control shaft. See Paragraph 11.1.2 for explicit instructions.

CHART E

METER POINTER UNDERDAMPED AND/OR VERY SLOW TO RESPOND TO pH CHANGES:

Disconnect electrodes, insert 700 Terminal Connector into INPUT receptacle and connect to REFERENCE receptacle with 8980 Shorting Strap. Turn Asymmetry Control and observe meter response.

METER RESPONSE IS NORMAL:

Check electrode circuit and electrodes. See if reference electrode needs refilling or if liquid junction is clogged. Check solution grounding (See Para. 3.4).

RESPONSE IS SLUGGISH, UNDERDAMPED:

Test circuit gain as follows: Press EXP and +MV push-buttons and turn Asymmetry Control to make meter read 7 pH. Then, while watching meter reading, connect 18,000 ohm resistor from the junction of R7 — R15 (+18V, on amplifier board) to collector of transistor Q4. Meter reading should change less than one millivolt. Wait for pointer to come to rest before taking readings.

ELECTRODE CIRCUIT AND ELECTRODES ARE GOOD:

Press STANDBY push-button, disconnect 700 Terminal Connector and 8980 Shorting Strap, and plug Beckman 71963 (1000 megohm) Resistor into input receptacle. Insert resistor lead into reference receptacle. Press pH push-button. Turn Asymmetry Control and observe meter.

READING IS GOOD:

Symptoms in preceding steps make this unlikely. Check alternate symptoms.

READING CHANGES MORE THAN ONE MILLIVOLT:

Test preamplifier gain as follows:
Connect 1000 ohm resistor to red lead circuit of chopper drive coil. Connect 10 ohm resistor to yellow lead circuit of chopper drive coil. Satisfactory to connect to green leads of transformer T1, but must observe polarity. Resistors factor of 10 larger or smaller may be used, but keep 100:1 ratio. Connect free ends of resistors together and connect lead from this junction to a 2 MEG resistor. Connect other end of 2 MEG resistor to end of R15 (39K) which goes to pin 2 of preamplifier. Meter reading should change less than one millivolt. (Wait for pointer to come to rest before taking readings.)

METER RESPONSE NORMAL:

Instrument operating properly. Recheck electrode circuit.

METER RESPONSE SLUGGISH:

Replace preamplifier and/or chopper. Also check insulation of input circuit wiring.

READING IS GOOD:

Look for cause of low gain in amplifier. Compare potential readings with circuit diagram. Replace transistor associated with incorrect potential. If potential remains incorrect, replace related bypass or coupling capacitor, then check resistors.

NOTE: Transistor Q2 may be defective and yet circuit potentials may appear normal and operation almost normal. Response may merely be slow. To determine whether Q2 is good, perform circuit gain test described previously, first with, and then without, clip lead connected from base to emitter of Q2. If gain changes, Q2 is good.

READING CHANGES TOO MUCH:

Replace preamplifier.

AMPLIFIER IS GOOD:

Check a.c. ripple across capacitor C9 (connect a.c. meter or oscilloscope from Q4 base to junction of R7 — R15.) Should be less than 200 millivolts, RMS.

RIPPLE IS HIGH:

Replace C9.

RIPPLE IS GOOD:

Check demodulator (by measuring d.c. potential from base of transistor Q4 to accessible end of resistor R24) while turning demodulator balance control, R32 (on power supply). Should be able to obtain positive and negative potentials of about one volt.

POTENTIAL IS NOT CORRECT:

Check potentiometer R32 and other parts of demodulator circuit. Also check a.c. potentials from transformer T1 to demodulator. After repairing fault, reset demodulator balance control, R32, according to instructions below:

Disconnect amplifier-to-power supply cable at amplifier and connect volt-ohm-milliammeter (20,000 ohms per volt preferred) between pins 3 and 6 of disconnected plug. Turn demodulator balance control to give zero reading on most sensitive d.c. current range of VOM meter. Then check reverse currents of demodulator diodes by switching to lowest d.c. voltage range of VOM meter. Reading greater than two or three smallest scale divisions (depending on make and model of VOM meter) indicates that at least one of diodes should be replaced, after which the preceding adjustment must be made again. If both readings (current and voltage) are satisfactory, adjustment is correct. Disconnect VOM meter and plug in cable connector.

CHART F

METER NEEDLE OSCILLATES:
Press STANDBY push-button.

OSCILLATION CONTINUES:
Temporarily connect 1000 MFD capacitor across capacitor C9 (connect to base of transistor Q4 and junction of R7 R15..

OSCILLATION CONTINUES:
If power supply is not in regulation or in some way no longer has low internal impedance, meter may oscillate at some level of power line potential. Noise usually accompanies this fault, allowing fault to be most easily located by following noise-testing procedures in chart B (Reading is less than one volt.)

OSCILLATION CEASES:
Replace capacitor C9.

OSCILLATION STOPS:
Look for open capacitor C3 (at STANDBY switch).

C3 IS GOOD:
Is glass electrode lead more than 20 feet long? If so, the stray capacity it introduces must be offset by increasing the size of capacitor C3. Change C3 to a polystyrene dielectric .005 MFD capacitor, to allow use of cable up to 200 feet in length. If polystyrene capacitor is not available, obtain some other type having an insulation resistance of 10^7 ohms or more.

C3 IS OPEN
Replace it.

CHART G

METER ACCURACY GOOD, BUT ELECTRODES GIVE FAULTY READINGS:
Check electrode circuit and electrodes. Perhaps reference electrode needs refilling or liquid junction is clogged.

ELECTRODES ARE GOOD:
Read the solution-grounding section and connect solution ground wire.

SOLUTION GROUND WIRE DOES NOT ELIMINATE TROUBLE:
Temporarily disconnect wire from SOLUTION GND terminal. Measure resistance from SOLUTION GND terminal to REFERENCE terminal. Should be at least 1000 megohms and relatively long time should be required for resistance reading to reach final value, indicating that capacitor C2 is good.

RESISTANCE AND RESPONSE GOOD:
Press STANDBY push-button, and plug Beckman 71968 (1000 megohm) resistor into nput receptacle. Apply simulated pH potential between the 71968 resistor lead and the reference receptacle. Press pH push-button and check meter accuracy.

RESISTANCE LOW, OR READING RESPONDS RAPIDLY:
Replace capacitor C2.

ACCURACY NOT GOOD:
Replace preamplifier and/or chopper. Also check insulation of input circuit wiring.

ACCURACY GOOD:
Instrument is operating properly. Recheck electrode circuit.

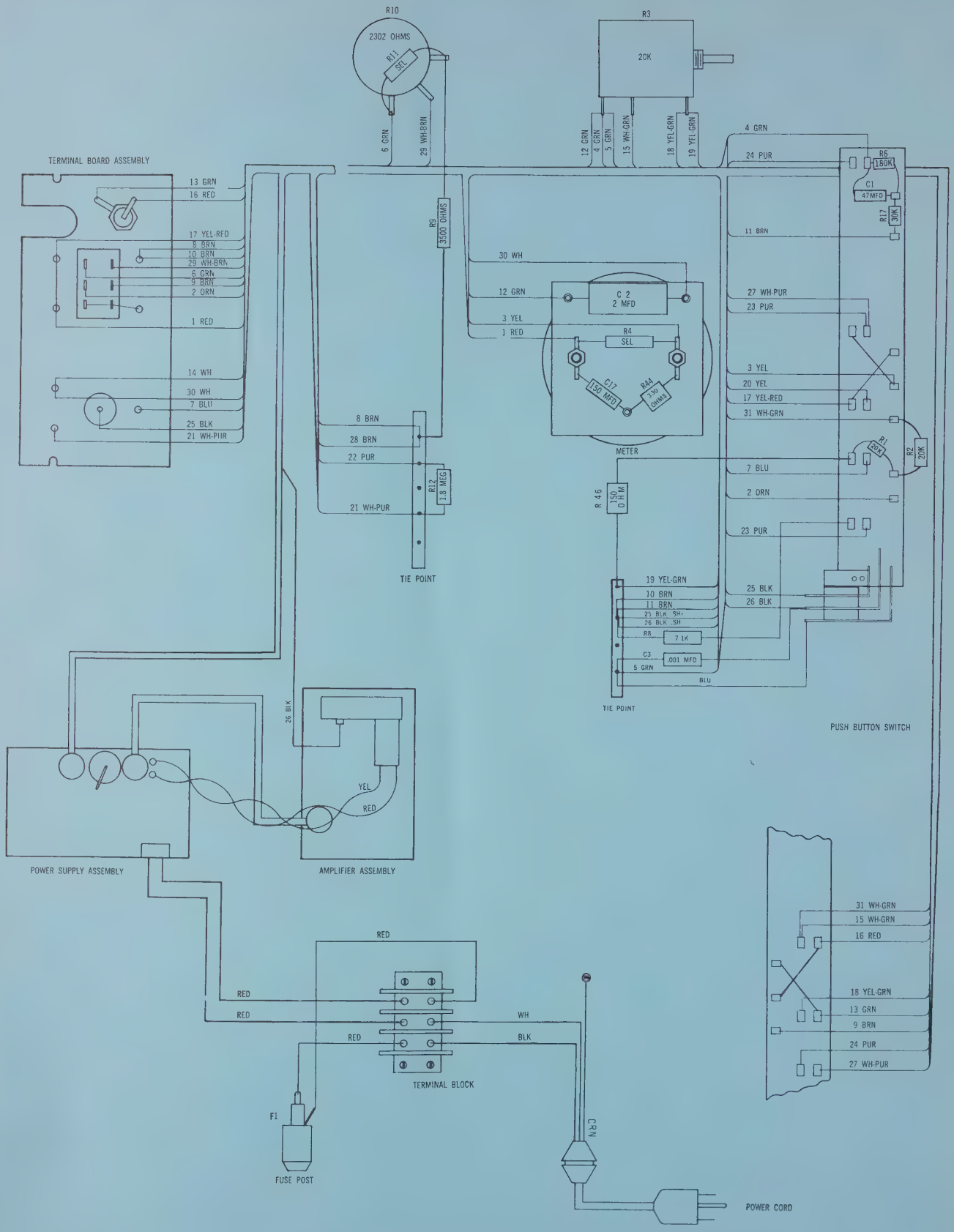


Figure 15. Pictorial Wiring Diagram

11.1 REPLACEMENT PROCEDURES

The replacement procedures in the following paragraphs cover only those components which require detailed instructions to replace. Refer to Figures 15 and 16 to complement these instructions when replacing other components not dealt with in this section. Be sure that the pH meter is disconnected from the power line before replacement procedures are begun. Hand tools required are: long nose pliers, screwdriver, Allen wrenches and a soldering iron.

11.1.1 TEMPERATURE COMPENSATOR POTENTIOMETER

To replace the temperature compensator potentiometer (2, Figure 26), first detach the chassis from the case. Unplug the cable connecting the case and the power supply assembly, and unplug the lead from the preamplifier assembly. Unsolder the leads from the three terminals on the potentiometer (circuit reference R10, Figures 15 and 16). Loosen the setscrew on the control knob and remove the knob. Take special care when removing the knob to see that the metal insert protecting the potentiometer shaft from damage by the setscrew is not lost and that it is in proper position when the knob is replaced. If the setscrew is tightened without the insert in position, the shaft will be scored and it will be impossible to make fine adjustments of the knob relative to the temperature calibrations. Remove the temperature dial by prying it from the case to break the glue seal. The potentiometer may be removed after the retainer nut holding it to the case has been unscrewed. When installing the new potentiometer, be certain that the two tabs fit into the corresponding slots on the inside of the case. Refer to Figure 15 to solder the leads to the correct terminals after the new potentiometer is mounted. Reassemble the instrument, but do not replace the Temperature Compensator Control knob. The temperature dial may be reglued to the case if acetone is spread over the glue. The potentiometer must be calibrated as instructed in the following paragraph.

11.1.2 TEMPERATURE COMPENSATOR CALIBRATION

Whenever a temperature compensator potentiometer is replaced, the new potentiometer must be calibrated relative to the graduations on the temperature dial. Several methods may be used to accomplish this.

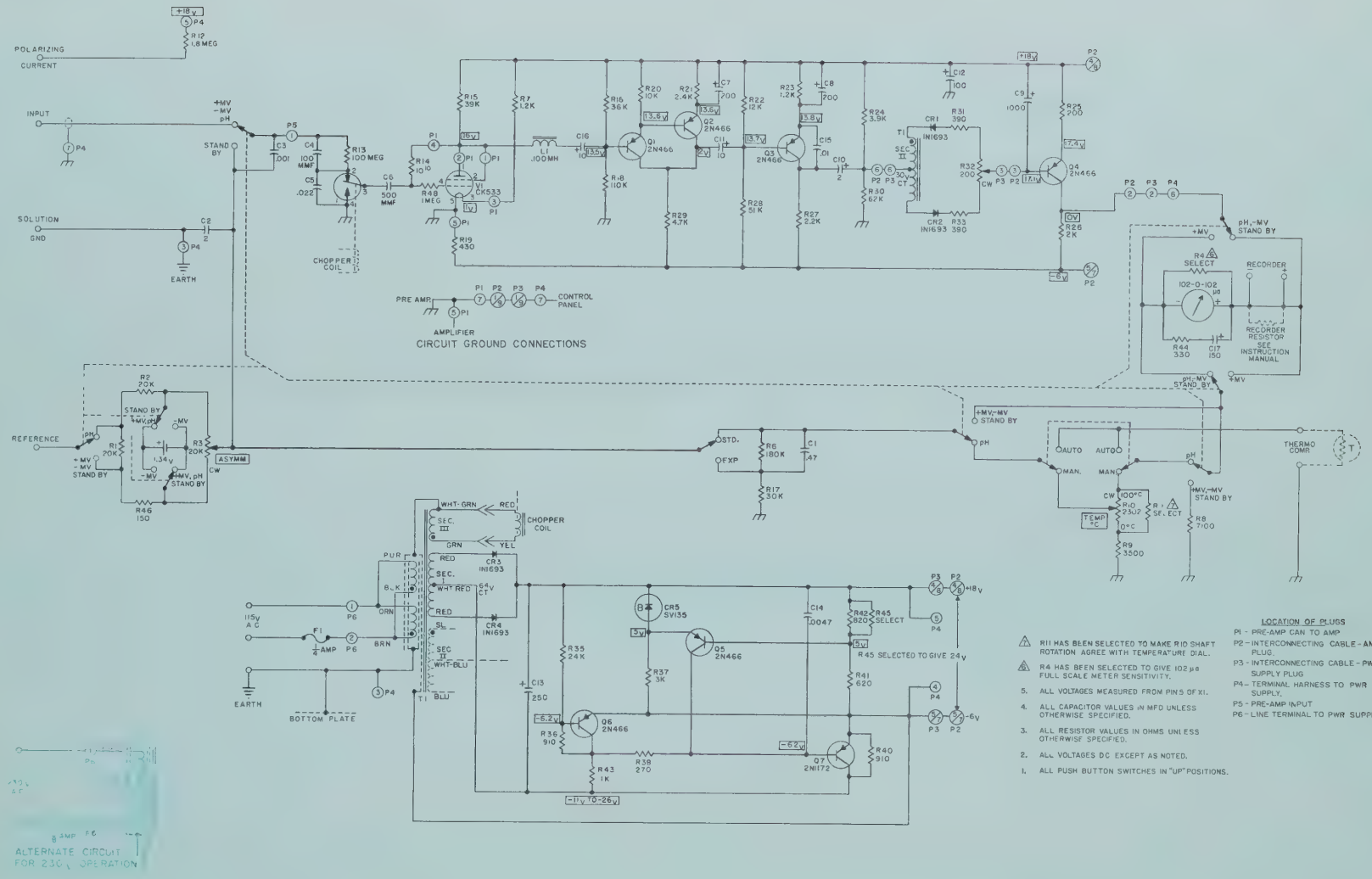
The following procedure is recommended for calibration of the manual temperature control:

1. Obtain one or more of the following resistors which correspond to the thermo-compensator resistance at the temperature shown:

3787 ohms	0°C
4142 ohms	25°C
4312 ohms	37°C
5207 ohms	100°C

   (Usually, the required resistance can be dialed directly on a resistance-measuring bridge in a manner similar to that in which a utility decade resistance box is used.)
2. Disconnect electrodes and place a 700 Terminal Connector in glass electrode (INPUT) terminal. Then connect a 8980 Shorting Strap between Terminal Connector and reference terminal.
3. Connect selected resistance across thermo-compensator terminals and switch to AUTO position of Thermo-Compensator Switch.
4. Press STD and pH push-buttons and turn Asymmetry Control to make meter read 14 pH.
5. Switch to MAN temperature control.
6. Turn Temperature Compensator Control to make meter read 14 pH.
7. Temperature dial reading should be same as temperature to which the resistance corresponds. Note error in temperature dial reading.
8. Connect another resistance across thermo-compensator terminals and repeat steps 3-7.
9. If temperature dial errors are consistently in one direction, loosen knob set screw, slip knob slightly relative to control shaft to obtain a better compromise of errors, then re-tighten set screw.

An alternate method requires the use of an auxiliary potentiometer with a readable and adjustable potential source, such as a student's potentiometer. Connect phone-tip leads to this potentiometer and plug the (+) lead to the glass electrode (INPUT) terminal, using a 700 Terminal Connector, and the (−) lead into the reference electrode terminal of the pH meter. Rotate the Asymmetry Control to the extreme clockwise position. Depress the STD and +MV push-buttons. Apply a potential of −414.1 millivolts (corresponding to 14 pH at 25°C) to the input terminal relative to the reference terminal. Turn the shaft of the temperature compensator potentiometer until the meter needle indicates exactly 14 pH on the standard scale. Without changing the setting, lock the knob on the temperature compensator potentiometer shaft, so that it points to 25 on the dial.


POLARIZING CURRENT
INPUT
SOLUTION
GND
EARTH
STAND BY
CHOPPER COIL
PRE AMP
CONTROL PANEL
AMPLIFIER
CIRCUIT GROUND CONNECTIONS
REFERENCE
ASYMM
STD.
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AUTO
MAN.
TEMP °C
RECORDER
RECORDER RESISTOR SEE INSTRUCTION MANUAL
SELECT
115v AC
BOTTOM PLATE
ALTERNATE CIRCUIT FOR 230v OPERATION
LOCATION OF PLUGS
P1 - PRE-AMP CAN TO AMP
P2 - INTERCONNECTING CABLE - AMP PLUG
P3 - INTERCONNECTING CABLE - PWR SUPPLY PLUG
P4 - TERMINAL HARNESS TO PWR SUPPLY.
P5 - PRE-AMP INPUT
P6 - LINE TERMINAL TO PWR SUPPLY.
1. ALL PUSH BUTTON SWITCHES IN "UP" POSITIONS.
2. ALL VOLTAGES DC EXCEPT AS NOTED.
3. ALL RESISTOR VALUES IN OHMS UNLESS OTHERWISE SPECIFIED.
4. ALL CAPACITOR VALUES IN MFD UNLESS OTHERWISE SPECIFIED.
5. ALL VOLTAGES MEASURED FROM PIN 5 OF X1.
R11 HAS BEEN SELECTED TO MAKE R10 SHAFT ROTATION AGREE WITH TEMPERATURE DIAL.
R4 HAS BEEN SELECTED TO GIVE 102 μa FULL SCALE METER SENSITIVITY.
R45 SELECTED TO GIVE 24v

Figure 16. Schematic Wiring Diagram

If the only auxiliary potentiometer available is one without a meter to indicate the amount of potential, it may be used in conjunction with a 1½ volt flashlight battery to calibrate the temperature compensator potentiometer. Connect the end terminals of this potentiometer across the battery. Connect the rotor of the poentiometer to the input terminal and the negative battery terminal to the reference terminal.

Rotate the Asymmetry Control to the extreme clockwise position. Depress the STD and the +MV push-buttons. Adjust the potential source until the Meter reads 414.1 millivolts. Disconnect the potential source but do not change the output and place a shorting strap between the input and reference terminals. Depress the pH push-button. Rotate the Asymmetry Control until the needle indicates exactly 7 pH. Remove the shorting strap and again connect the potential source. Do not change any of the settings. Rotate the shaft of the temperature compensator potentiometer until the meter reads zero pH. Without changing the setting, lock the knob on the temperature compensator potentiometer at 25 on the temperature compensator dial.

Another method of calibration utilizes two buffer solutions (preferably on the order of 4.01 and 9.18 pH). The temperature of the buffers must be identical. Rotate the temperature compensator potentiometer to mid position. Attach the knob temporarily so that it points to 25°C. Depress the STANDBY push-button. Immerse the electrodes in one of the buffer solutions. Depress the STD and pH push-buttons. Rotate the Asymmetry Control until the correct value is read on the standard scale. Depress STANDBY push-button, rinse electrodes and immerse them in the other buffer solution. Depress the pH push-button and rotate the Temperature Compensator Control until the correct value is indicated on the standard scale. Continue this process of alternate immersion in the buffers and corresponding alternate adjustments of the Temperature Compensator Control and Asymmetry Control until the pH of both buffers may be read without further adjustment. Lock the knob on the Temperature Compensator Control at the temperature of the two buffers.

11.1.3 ASYMMETRY CONTROL POTENTIOMETER

To replace the Asymmetry Control potentiometer, (1, Figure 26), first detach the chassis from the case. Unplug the cable connecting the case and the power supply assembly, and unplug the phone-tip lead from the potentiometer (circuit reference R3, Figures 15 and 16). Loosen the setscrews on the control knob and remove the knob, as well as the escutcheon plate retainer nut that screws onto the potentiometer bushing. Remove the escutcheon plate (the Range Indicator remains on) by prying up to break the glue seal holding it to the case. The potentiometer may then be removed after the retainer nut holding it to the case is unscrewed from the shaft. When installing the new potentiometer, be certain that the two tabs fit into the corresponding slots on the inside of the case to keep the potentiometer in position. Refer to Figure 15 to solder the leads to the correct terminals after the new potentiometer is mounted. Enough glue will remain on the escutcheon plate so that it will stick if acetone is spread over the glue.

11.1.4 METER

To replace the meter, first remove the chassis. Remove the board assembly (13, Figure 26) attached to the meter. Detach the four brackets holding the meter to the case. Take them off completely rather than bend them, otherwise they will not hold the meter firmly when it is replaced. The meter may then be removed easily.

11.1.5 PUSH-BUTTON SWITCH ASSEMBLY

The push-button switch assembly (18, Figure 26) may be removed by first unsoldering all of the leads from it. Take out the screw from one end of the switch and loosen the one at the other end that holds it to the case. The push-buttons can be pulled off when the switch is lifted out. Refer to Figure 15 when attaching the leads to the new switch.

11.1.6 PREAMPLIFIER ASSEMBLY

The preamplifier assembly (3, Figure 28) is sealed and must be replaced as one unit. Access to the preamplifier is gained by removing the chassis from the case. Unplug the phone-tip lead from the preamplifier, and remove the chopper assembly as described in the following paragraph. Remove the screw, accessible through a hole in the bottom of the chassis, that secures the assembly to the amplifier board. The preamplifier may then be unplugged from the socket in the amplifier board by pulling straight out. When installing a new assembly, be certain that it is secured again with the screw.

11.1.7 CHOPPER ASSEMBLY

Remove the chassis from the case. The chopper assembly (2, Figure 28) is mounted on the preamplifier assembly. However, it is not necessary to remove the preamplifier assembly to replace the chopper or its drive coil. The chopper cover is removed by pushing it in and twisting counterclockwise. The coil will then slip off of the chopper, and the chopper can be unplugged from the socket on the preamplifier assembly by pulling straight out. If necessary, pry carefully through one of the side holes of the socket shell with a small screwdriver. Unplug the two leads from the power supply board if the coil is to be replaced. Socket, cover, chopper and coil come as one replacement part; the socket is also included as an integral part of the preamplifier assembly.

11.1.8 AMPLIFIER ASSEMBLY

Access to the amplifier assembly (4, Figure 28) is gained by removing the chassis from the case. Remove the preamplifier assembly as instructed in Paragraph 11.1.6 (do not remove the chopper assembly from it). Unplug the cord leading to the power supply board. Detach the amplifier board at the four corners where attached to the chassis.

11.1.9 POWER SUPPLY ASSEMBLY

To remove the power supply assembly (5, Figure 28), first remove the chassis from the case. Unplug the two leads that are attached to the chopper. Unplug the cord from the amplifier board, the cord leading to the case, and the cord leading to the fuse. Detach the four corners of the power supply board from the chassis to permit the removal of the assembly.

11.1.10 MERCURY BATTERY

The only component of the terminal board assembly that will require regular replacement is the mercury battery, which has a normal service life of about one year. To remove the battery, a coin may be used to unscrew the plug from the top of the battery holder (3, Figure 27). Hold onto the plug until it is unscrewed completely, for the battery is held in electrical contact by a strong spring which can forcefully throw the battery out of the holder if the plug is removed suddenly. Be careful to see that the new battery is placed with the positive (+) end outward.

11.2 TESTING REFERENCE ELECTRODES

The accuracy of Beckman Reference Electrodes can be checked easily on the Expanded Scale pH Meter. Connect the questionable reference electrode to the pH meter in the usual manner and plug a new reference electrode (one that is known to be good) into the glass electrode (INPUT) terminal. Use a Beckman 700 Terminal Connector. A reference electrode with a calomel internal element may be used to check an electrode with a silver-silver chloride internal element, or vice versa.

Set the pH meter to read in millivolts on the expanded scale. Take readings with this pair of reference electrodes in a beaker of buffer solution and then in a beaker of electrolyte (KCl) solution. The potential readings in the two solutions should be identical and also should be zero ±5 millivolts, if the electrodes have the same internal element. If an electrode with a calomel internal element is in the glass electrode (INPUT) terminal and is being used to check one with a silver-silver chloride internal element, the reading should be +44 ±5 millivolts; the reverse situation should give a reading of −44 ±5 millivolts.

If the reading obtained in the electrolyte solution is zero (or ±44 ±5 millivolts) and the reading obtained in the buffer solution is not zero (or ±44 ±5 millivolts) the liquid junction is clogged. A clogged junction, especially palladium and sleeve junctions, may be cleared by placing the immersion tip in a beaker of distilled water and boiling for a short time. However, a fiber junction may be clogged so thoroughly that this treatment will not suffice. In this case, spread a fine abrasive on a flat glass surface and rub the electrode tip lightly over it until the electrolyte solution begins to flow through the junction. This flow can be verified by repeating the preceding test. Do not grind the tip any more than is necessary to clear the junction. Excessive grinding will cause the electrolyte solution to flow too rapidly, requiring frequent replenishment, while severe grinding will destroy the fiber junction.

CAUTION

Do not, under any circumstances, attempt to free a clogged palladium junction by grinding it. To do so will damage the electrode beyond repair.

If the readings in both the buffer and electrolyte solutions are not zero (or ±44 ±5 millivolts), it is because of a faulty internal element and the electrode should be discarded.

Figure 17. The Thermomatic and the Micro Blood pH Assembly

Section 12. Accessories

Accessories that may be used to greatest advantage with the Expanded Scale pH Meter are described in this section. For more information on these and other accessories, contact an authorized Beckman Laboratory Apparatus Dealer or write directly to Beckman Instruments, Inc.

12.1 THE THERMOMATIC

The Beckman Thermomatic Constant Temperature Block, Figure 17, is designed primarily to maintain blood and other body fluids at a constant temperature during pH and other electrochemical-potential measurements. Although pre-set to keep fluids at body temperature (37°C), the Thermomatic can be adjusted to maintain any temperature between 30°C and 50°C. A constant sample temperature can be held through a variation of ±5°C in ambient temperature. Receptacles in the top of the instrument permit additional samples to be brought to thermal equilibrium while measurements are being conducted.

The Beckman 28505 Thermomatic is for 115-volt operation and the Beckman 28506 Thermomatic is for 230-volt operation.

12.2 THE MICRO BLOOD ASSEMBLY

The Beckman Micro Blood Assembly, Figure 17, in conjunction with the Expanded Scale pH Meter, permits precise measurements under anaerobic conditions on small samples of blood or other body fluids. No more than ¼ to ½ ml of sample is required.

Several Micro Blood Assemblies—differing only in their sensing electrode—are available for specific applications: Beckman 46850 Assembly is for pH measurements; Beckman 77446 Assembly is for sodium ion measurements; Beckman 77447 Assembly is for measurement of various monovalent cations; and Beckman 77448 Assembly is for measurement of chloride ions. The assemblies are designed to mount in the Thermomatic Constant Temperature Block.

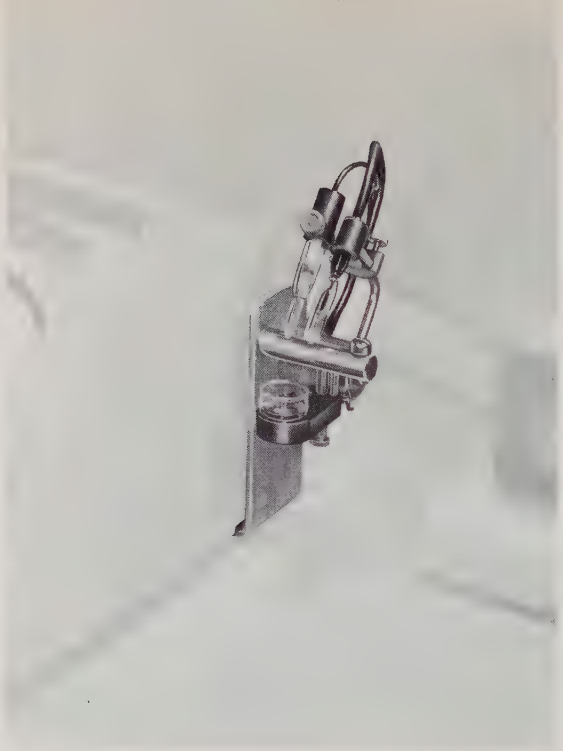


Figure 18. Swing Arm Assembly

12.3 SWING ARM ADAPTOR AND SWING ARM ASSEMBLIES

These accessories increase the convenience and rapidity with which measurements may be made with the Beckman Expanded Scale pH Meter, utilizing Beckman small size electrodes. Features of the swing arm dispense with the need for lifting individual electrodes in and out of each sample. Instead, both electrodes are swung as one unit with the electrode holder — greatly facilitating measurement procedures. Each accessory is interchangeable with the rigid electrode holder normally mounted on the Expanded Scale pH Meter.

The 73064 Swing Arm Adaptor consists of a swing arm electrode holder, a holder for a 5 ml beaker, and a bracket for attaching the unit to the meter. The 73065 Swing Arm Assembly consists of the above Swing Arm Adaptor and a 5 ml beaker; while the 73066 Swing Arm Assembly (Figure 18) is equipped with small size reference and general purpose glass electrodes, in addition to the above components. Each of these accessories will accommodate many of the great variety of Beckman small size electrodes available for specific applications. Temperature range of these electrodes is −5° to 50°C.

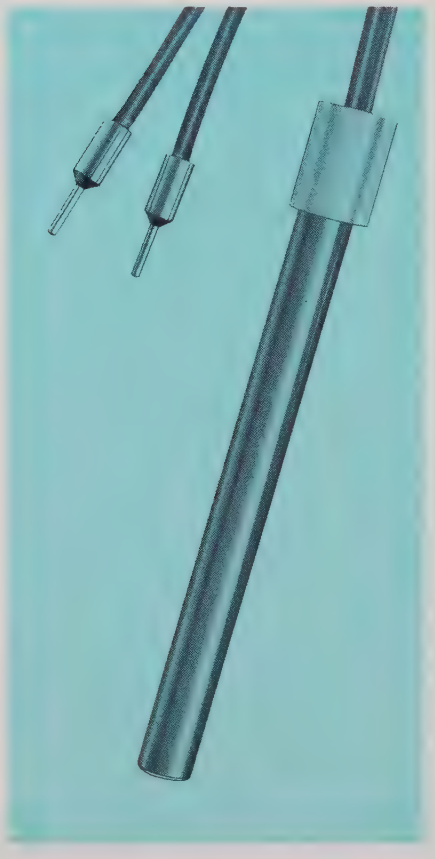
12.4 39096 THERMO-COMPENSATOR

The Beckman 39096 Thermo-Compensator (Figure 19) designed for use with the Expanded Scale pH Meter, is a resistance thermometer which automatically compensates for temperature variations in the solutions under study.

Utilization of the Thermo-Compensator automatically provides a correction for pH scale changes at different temperatures, so that the meter indicates the correct pH reading at the temperature of measurement. However, it does not provide compensation for changes in the solution due to varying hydrogen ion activity at different temperatures.

The Thermo-Compensator has a thermal response time comparable to that of most electrode systems. Thermal equilibrium time for this temperature-sensitive unit depends upon the temperature change; that is, difference between temperature of solution and that of the Thermo-Compensator.

Figure 19. The Thermo-Compensator



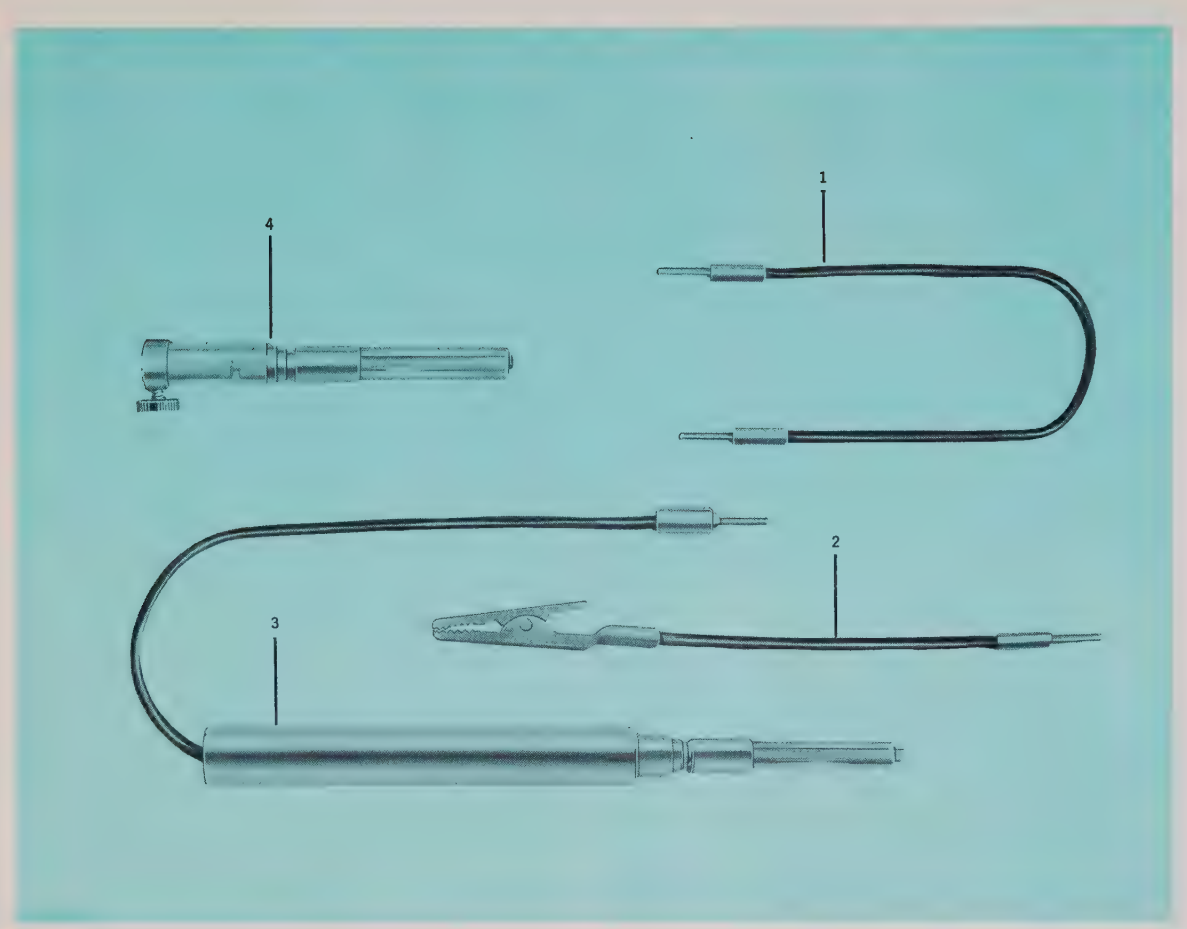


Figure 20. Minor Accessories

1 8980 SHORTING STRAP 2 5083 POLARIZING JUMPER 3 71968 RESISTOR 4 700 TERMINAL CONNECTOR

12.5 MINOR ACCESSORIES

Several minor accessories, shown in Figure 20, can be utilized with the Expanded Scale pH Meter.

The 71968 Resistor is used to check the leakage current of the instrument. One end of the resistor has the correct lead to fit into the input terminal without the need of a special terminal connector. The other end has a phone-tip termination that fits the reference electrode terminal.

The 700 Terminal Connector adapts the glass electrode terminal so that phone-tip leads may be connected. This accessory is commonly used in the testing of reference electrodes and for titrations with the Expanded Scale pH Meter.

The 5083 Polarizing Jumper is designed specifically for performing titrations with the Expanded Scale pH Meter. It must be used with the 700 Terminal Connector.

The 8980 Shorting Strap is used in conjunction with the 700 Terminal Connector to connect the INPUT and REFERENCE electrode terminals for test purposes. It also provides a simple means of shifting the range of the expanded scale to ±200 millivolts.

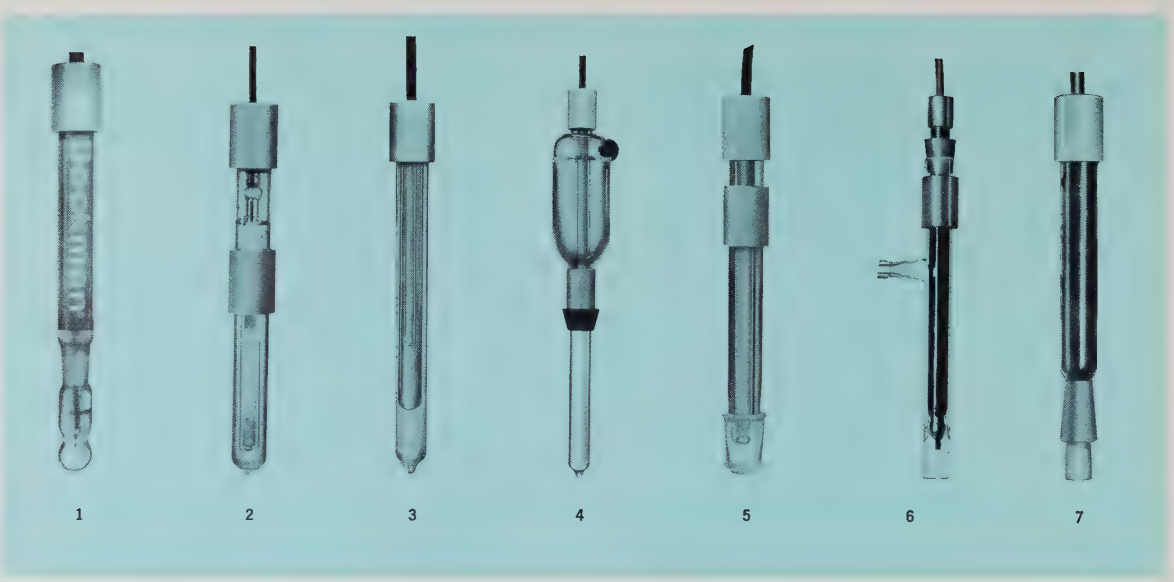


Figure 21. Typical Electrodes for use with the Expanded Scale pH Meter

1 GLASS ELECTRODE
2 FIBER JUNCTION REFERENCE ELECTRODE
3 SEALED DOUBLE JUNCTION REFERENCE ELECTRODE (FIBER)
4 PALLADIUM ANNULUS JUNCTION REFERENCE ELECTRODE
5 SLEEVE JUNCTION REFERENCE ELECTRODE
6 HYDROGEN ELECTRODE
7 SILVER-SILVER CHLORIDE PRESSED BILLET ELECTRODE

12.6 TYPICAL ELECTRODES

Although there is a great variety of Beckman Electrodes that may be used for special applications, only a few of the typical are shown in Figure 21.

Glass electrodes are catalogued according to the type of pH sensitive glass — General Purpose, E-2 and Amber — used for the immersion tips. The General Purpose electrodes, one of which is shown in 1, Figure 21, are the most versatile. The other two types have particular characteristics that make them applicable for measurements not possible with the General Purpose electrode.

Reference electrodes (2-5, Figure 21) differ primarily in the type of liquid junction — fiber, sleeve and palladium annulus. Fiber junction reference electrodes are chemically inert and are used in most applications. Sleeve junction reference electrodes are used where a high volume flow rate of electrolyte solution is desired, and are particularly suitable for measurements of viscous and highly saturated samples that would clog other junctions. Palladium annulus reference electrodes have an extremely low flow rate and are used to great advantage in pressurized media.

The 39282 Hydrogen Electrode (6, Figure 21) is one of the many electrodes manufactured by Beckman Instruments, Inc. for specialized applications. It is an immersion electrode of the Hildebrand type, designed for studies of a theoretical nature involving pH and electrochemical potential measurements. The hydrogen electrode is the primary standard upon which the modern definition of pH is based. All other methods of pH measurement are indirect, and their accuracy must be checked relative to the hydrogen electrode or by standardization with buffer solutions whose pH values are obtained relative to the potential of a hydrogen electrode.

Metallic electrodes are selected primarily for the particular ion in solution which must be measured. The Beckman Silver-Silver Chloride Pressed Billet Electrode shown in 7, Figure 21, is specifically designed for use in the continuous measurement of chloride ion concentrations. A blended powder of silver and silver chloride molded together under very high pressure forms the solid billet of the electrode. This feature provides the electrode with an extremely long life and the capability of withstanding rugged treatment and abrasion.

For a complete catalog of Beckman Electrodes, pH accessories, Buffer and Filling Solutions, ask your Beckman Dealer for Bulletin 86, or write:

Beckman Scientific and Process Instruments Division, 2500 Harbor Blvd., Fullerton, California

12.7 LABORATORY POTENTIOMETRIC RECORDER

The Beckman Laboratory Potentiometric Recorder (Figure 22) is especially designed for use with the Expanded Scale pH Meter and other Beckman laboratory instruments. This compact recorder may be mounted horizontally on a bench or vertically on a panel or wall. Presentation is normally on a five-inch continuous chart, but an accessory readily adapts the instrument for twenty-four hour circular-chart recording. Normal chart speed is one-inch per minute; auxiliary internal and external chart-drive motors are available to provide a wide selection of chart speeds. Sensitivity span of the recorder is variable from 10-100 millivolts. For information related to the pH meter-recorder circuit, refer to Paragraph 13.1.

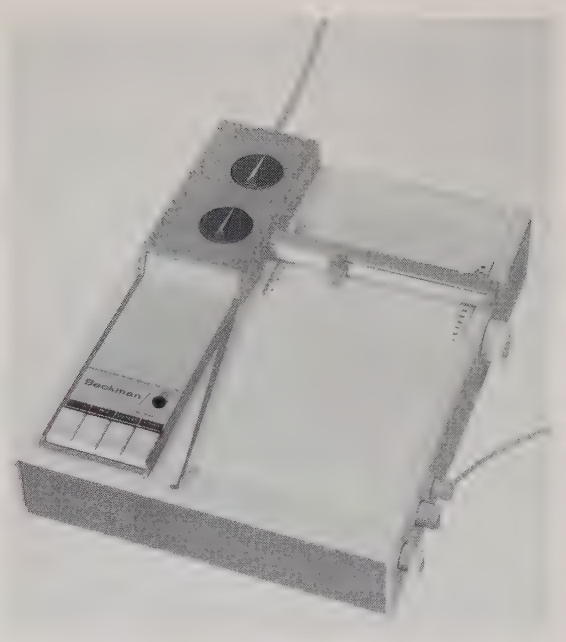


Figure 22. Laboratory Potentiometric Recorder

12.8 RECORDER RESISTORS

A variety of recorder resistors are available for installation in the Expanded Scale pH Meter to adapt it for operation with a potentiometric recorder. The "zero" point of the recorder should be at mid-scale, however. The resistance required for proper recorder operation may be computed from the recorder sensitivity and the sensitivity of the meter in the Expanded Scale pH Meter.

Example:

Meter sensitivity 204 microamperes full scale.
Recorder sensitivity 50 millivolts full scale.

Apply Ohm's Law:

$$R\,(\text{ohms}) = \frac{E\ (\text{volts})}{I\ (\text{amps})} = \frac{\text{Recorder Sensitivity (volts)}}{\text{Meter Sensitivity (amps)}}$$

$$= \frac{50 \times 10^{-3}}{204 \times 10^{-6}} = .2451 \times 10^{3} = 245.1$$

Therefore, for a recorder with a sensitivity of 50 millivolts, a resistor with a value of 245.1 ohms is required. Resistor tolerances of 1% will suffice for most applications.

Figure 23 lists the specifications of various resistors that may be obtained through your Beckman Dealer to adapt the Expanded Scale pH Meter for operation with a potentiometric recorder.

Recorder Sensitivity (Millivolts)	Description	Beckman Part Number
10 MV	Resistor, 49.02 ohms ±.1% ¼ W	79696
35 MV	Resistor, 171.6 ohms ±.1% ¼ W	79695
50 MV	Resistor, 245.1 ohms ±.1% ¼ W	79698
70 MV	Resistor, 343.1 ohms ±.1% ¼ W	79697
100 MV	Resistor, 490.2 ohms ±.1% ¼ W	79694

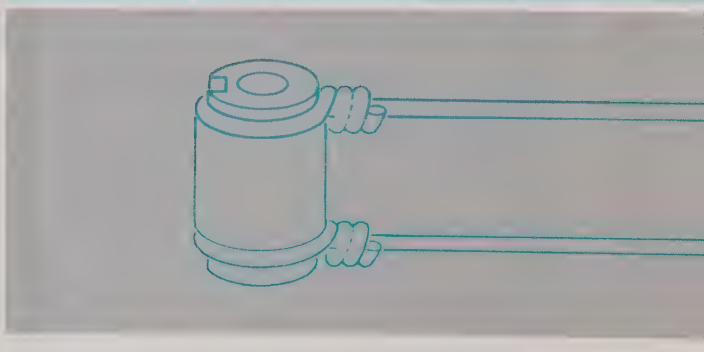


Figure 23. Recorder Resistors

Section 13. Recorder Installation

Installation of a recorder enables the Expanded Scale pH Meter to be used for rapid and continuous measurements of solutions wherein the pH or millivolt values are not constant. The Beckman Laboratory Potentiometric Recorder, described in Paragraph 12.7, is ideally suited for use with the instrument. Since the input voltage span of this recorder is variable, from 10-100 millivolts, any recorder resistor between 49 and 490 ohms may be used (a precision resistor is unnecessary), and the recorder span can be adjusted to the selected meter span of the Expanded Scale pH Meter. Most other potentiometric and current recorders also may be used; for this reason, the directions presented here are somewhat general in nature. If any questions arise with a particular recorder, contact your Beckman Authorized Laboratory Apparatus Dealer.

13.1 POTENTIOMETRIC RECORDER

This type of recorder with a sensitivity of 200 millivolts or less may be employed. Zero is at center scale, or the zero-shifting network may be used (see Figure 24). If this type of recorder is used, the Expanded Scale pH Meter must be equipped with a suitable recorder resistor. For the determination of proper resistors for use with recorders of various sensitivities, refer to Paragraph 12.8.

To install the recorder resistor and connect the potentiometric recorder to the instrument, proceed as follows:

1. Invert the instrument and detach the chassis.
2. Turn the instrument upright and carefully remove the case.
3. Locate the recorder terminals on the inside of the instrument terminal board.
4. Cut out the shorting strap across the recorder terminals, (this is installed so that the instrument will operate properly if the recorder is not used).
5. Solder recorder resistor across recorder terminals. It is unnecessary to remove the resistor if the recorder is to be disconnected and the instrument operated independently.
6. Replace the case and attach the chassis.
7. Install phone-tips on the recorder leads.
8. Connect recorder leads to recorder terminals on the instrument terminal board.
9. Refer to Paragraph 13.3 if difficulty is encountered due to recorder grounding.

NOTE

If the recorder is affected by alternating current pick-up, evidenced by sluggish response of recorder or by a change of meter reading at the moment when the recorder leads are connected, shield the recorder leads and connect the shield to the solution ground terminal on the instrument. Shield must be insulated from earth ground.

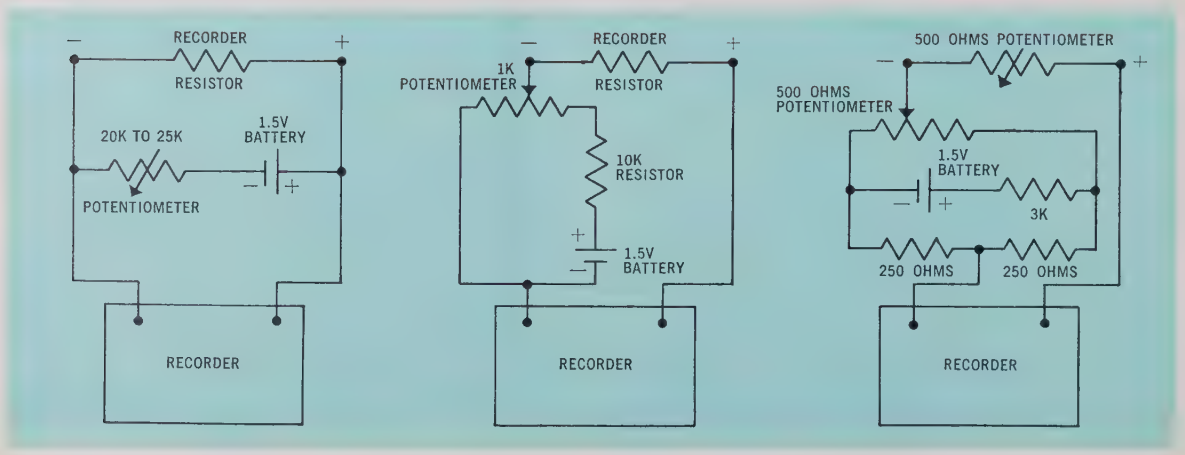
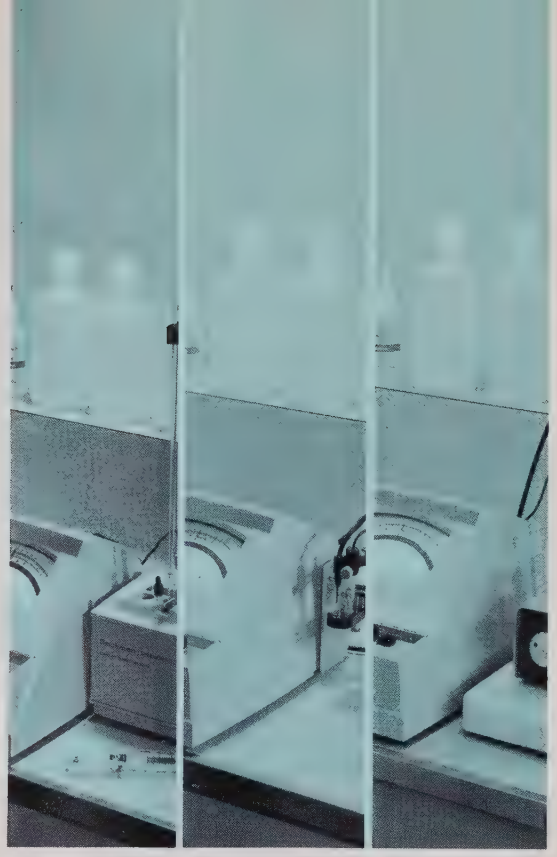


Figure 24. Typical Circuits for Shifting Zero Point on Non-Zero-Center Recorders



13.2 CURRENT RECORDER

A current recorder with a sensitivity of 204 microamperes and "zero" at the mid-point of the scale may be utilized with the Expanded Scale pH Meter. More sensitive recorders may be shunted to 204 microamperes. On this recorder, zero is at center scale, or the zero-shifting network may be used (see Figure 24). The resistance of the recorder must be less than 1000 ohms. A recorder resistor is not required on the instrument when operated with a current recorder.

To connect a current recorder to the instrument, proceed as follows:

1. Invert the instrument and detach the chassis.
2. Turn the instrument upright, and remove the case.
3. Locate the recorder terminals on the inside of the instrument terminal board.
4. Cut out the shorting strap across the recorder terminals — this is installed so the instrument will operate properly if a recorder is not used.
5. Replace the case and attach the chassis.

NOTE

If the recorder is disconnected and the instrument is operated independently, a shorting strap must again be placed on the recorder terminals on the instrument terminal board.

6. Install phone tips on the recorder leads.
7. Connect recorder leads to the appropriate terminals on the instrument terminal board.
8. Refer to Paragraph 13.3 if difficulty is encountered due to recorder grounding.

NOTE

If the recorder is affected by alternating current pick-up, evidenced by sluggish response of the recorder or by a change of meter reading at the moment when the recorder leads are connected, shield the recorder leads and connect the shield to the solution ground terminal on the instrument. Shield must be insulated from earth ground.

13.3 RECORDER GROUNDING

An accurate measurement cannot be obtained while a direct connection occurs between either of the recorder terminals and the reference electrode circuit. Therefore, when the solution cannot be isolated from the earth, isolation must be provided at the recorder — either the recorder input circuit must be isolated from the recorder case and from the a.c. power line, so that the recorder case may be grounded, or the entire recorder must be isolated from the earth and from the a.c. power line.

In addition, whether or not the solution connects to the earth, the recorder must not create an a.c. potential between either of its input terminals and any part of the pH meter. This difficulty usually can be prevented by use of a paper dielectric capacitor, 2 microfarads or more and rated at 100 volts or more, connected from the SOLUTION GROUND terminal to the negative recorder terminal. Also, use a power plug adapter at the pH meter power plug, leaving the pig-tail disconnected, and isolate the metal parts of the pH meter case from other conductive material. (See Figure 4.)

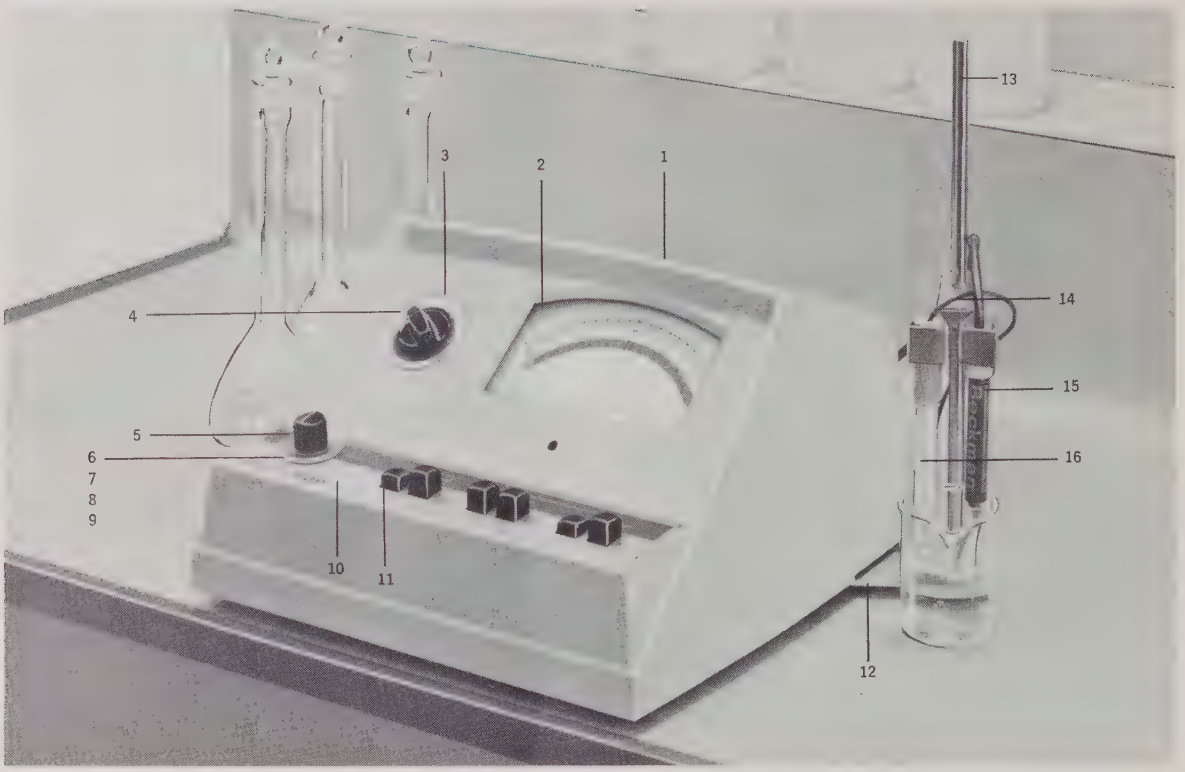


Figure 25. Outer Case Assembly

REFERENCE NUMBER	DESCRIPTION	CIRCUIT REFERENCE	PART NUMBER
1.	Case		73406
2.	Meter Assembly	M1	49691
3.	Plate, Temperature Dial		73405
4.	Knob, Temperature Compensator Control		811745
5.	Knob, Asymmetry Control		816809
6.	Indicator, Range (Attaching Parts)		49647
7.	Bushing		74015
8.	Washer, Wavy Spring		79117
9.	Ring, Retaining		79409
10.	Plate, Escutcheon		73403
11.	Pushbutton Assembly		73402
12.	Bracket, Electrode Holder		73062
13.	Rod, Electrode Support		16740
14.	Clip, Electrode		77330
15.	Electrode, Glass		41263
16.	Electrode, Reference		39170

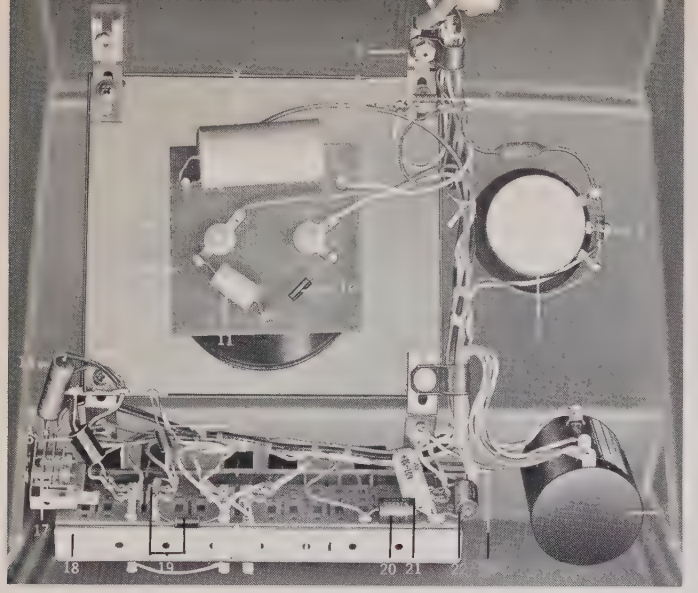


Figure 26. Inner Case Assembly

REFERENCE NUMBER	DESCRIPTION	CIRCUIT REFERENCE	PART NUMBER
1.	Potentiometer, Asymmetry, 20K	R3	810113
2.	Potentiometer, Temperature Compensator	R10	811193
3.	Resistor, Selected	R11	
4.	Resistor, 3.5K	R9	22766
5.	Resistor, 1.8-megohm	R12	8150
6.	Point, Tie		936
7.	Clamp, Cable		596
8.	Bracket, Meter		28878
9.	Capacitor, 2 MFD	C2	99062
10.	Resistor, 330-ohm	R44	15443
11.	Capacitor, 150 MFD	C17	79647
12.	Resistor, Selected (Beneath Board)	R4	
13.	Board Assembly		72030
14.	Point, Tie		92245
15.	Capacitor, .001 MFD	C3	43104
16.	Resistor, 7.1K	R8	79552
17.	Bracket, Switch		45076
18.	Switch, Push-Button		73039
19.	Resistor, 20K	R1, R2	15057
20.	Resistor, 30K	R17	811109
21.	Capacitor, .47 MFD	C1	811750
22.	Resistor, 180K	R6	811108
23.	Harness, Electrical		73024
24.	Resistor, 150-ohm	R46	15442

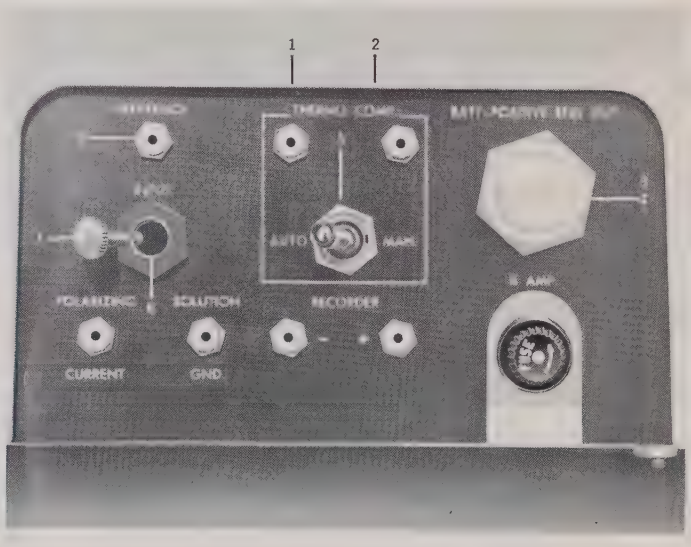


Figure 27. Terminal Board Assembly

REFERENCE NUMBER	DESCRIPTION	CIRCUIT REFERENCE	PART NUMBER
1.	Terminal Board Assembly		73026
2.	Board, Terminal		73028
3.	Holder, Battery		810097
4.	Battery, Mercury		29920
5.	Switch, Thermo-Compensator		29723
6.	Terminal, Glass Electrode		16625
7.	Screw, Thumb		296
8.	Terminal, Phone-Tip		16677

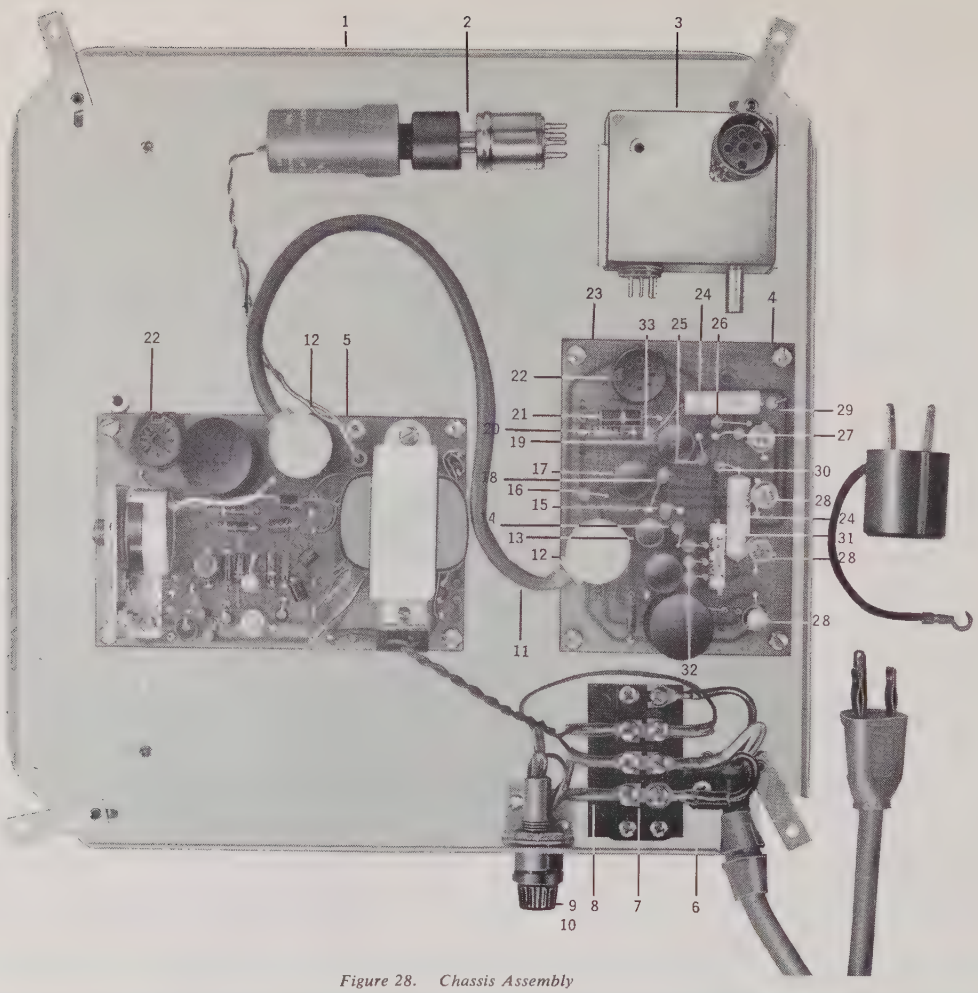


Figure 28. Chassis Assembly

REFERENCE NUMBER	DESCRIPTION	CIRCUIT REFERENCE	PART NUMBER
1.	Chassis		73055
2.	Chopper Assembly, Synchroverter		79385
3.	Preamplifier Assembly		73060
4.	Amplifier Assembly		73050
5.	Power Supply Assembly		73040
6.	Clamp, Cable		79350
7.	Block, Terminal		17027
8.	Marker, Terminal Strip		24994
9.	Post, Fuse		99599
10.	Fuse, ¼ ampere (115V Instrument)	F1	99403
11.	Cable, Double-Plug		73048
12.	Socket, Nine-Pin		99497
13.	Capacitor, 2 MFD	C10	802882
14.	Resistor, 2.2K	R27	897
15.	Resistor, 62K	R30	15069
16.	Resistor, 2.4K	R21	15451
17.	Capacitor, 200 MFD	C7, C8	827434
18.	Resistor, 3.9K	R24	15047
19.	Capacitor, 100 MFD	C12	802911
20.	Resistor, 39K	R15	15062
21.	Resistor, 1.2K	R7	8056
22.	Socket, Seven-Pin		99498
23.	Board, Eyeleted Circuit		73051
24.	Capacitor, 10 MFD	C16, C11	79494
25.	Resistor, 430-ohm	R19	15445
26.	Resistor, 10K	R20	15052
27.	Resistor, 36K	R16	7543
28.	Transistor, Special	Q2, Q3, Q4	71489
29.	Resistor, 110K	R18	15076
30.	Resistor, 4.7K	R29	899
31.	Capacitor, .01 MFD	C15	29839
32.	Resistor, 51K	R28	15067
33.	Inductor, .100 mh	L1	807902

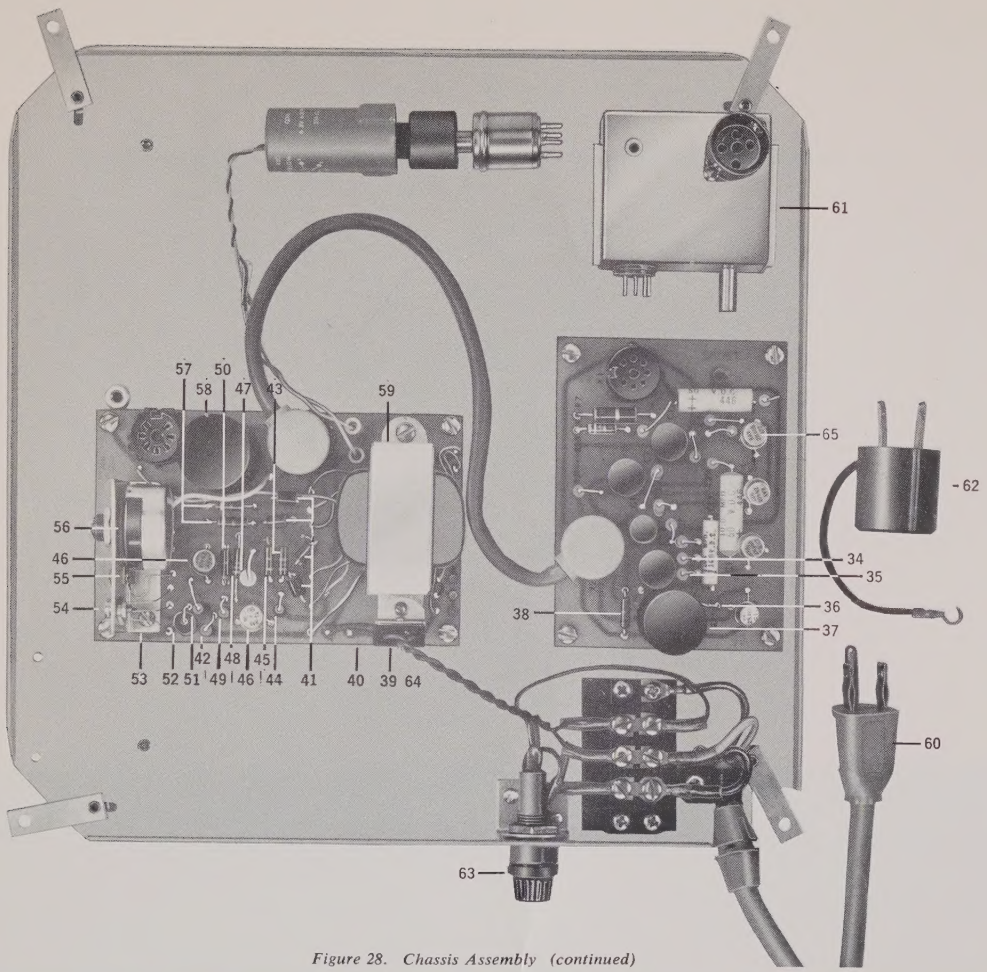


Figure 28. Chassis Assembly (continued)

REFERENCE NUMBER	DESCRIPTION	CIRCUIT REFERENCE	PART NUMBER
34.	Resistor, 12K	R22	29323
35.	Resistor, 1.2K	R23	15039
36.	Resistor, 200-ohm	R25	22931
37.	Capacitor, 1000 MFD	C9	802927
38.	Resistor, 2K	R26	15042
39.	Connector, 2 Pin Male		74389
40.	Board, Eyeleted Circuit		73041
41.	Diode	CR1, CR2, CR3, CR4	812476
42.	Resistor, 1000-ohm	R43	15038
43.	Resistor, 820-ohm	R42	79172
44.	Resistor, 620-ohm	R41	20411
45.	Resistor, Selected	R45	
46.	Transistor, Special	Q5, Q6	73451
47.	Capacitor, .0047 MFD	C14	29838
48.	Resistor, 24K	R35	7933
49.	Resistor, 910-ohm	R36	8748
50.	Resistor, 3K	R37	8845
51.	Resistor, 270-ohm	R38	800011
52.	Resistor, 910-ohm	R40	79266
53.	Bracket, Mounting		73043
54.	Transistor, 2N1172	Q7	810250
55.	Diode	CR5	29740
56.	Potentiometer, 200-ohm	R32	1954
57.	Resistor, 390-ohm	R31, R33	15444
58.	Capacitor, 250 MFD	C13	825301
59.	Transformer	T1	71962
60.	Cord, Power		73057
61.	Shield, Preamplifier		74350
62.	Adaptor, Three-Prong		16988
63.	Fuse, ⅛ ampere (230V Instrument)	F1	22768
64.	Connector, 2 Pin Female		806792
65.	Transistor, Special	Q1	71489

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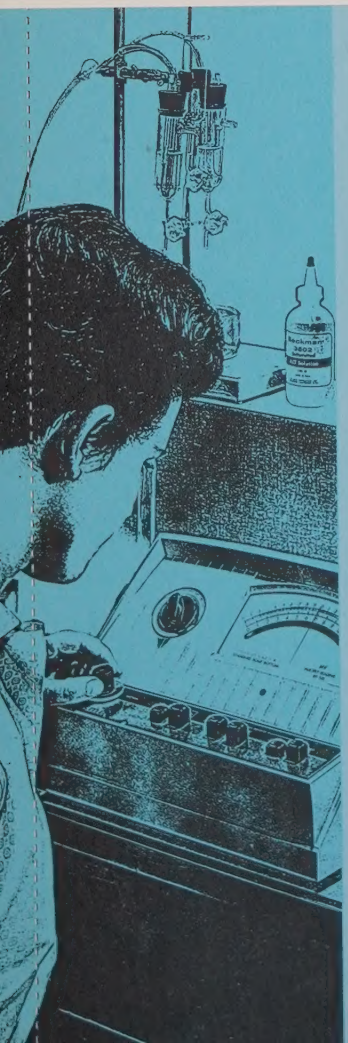

CONDENSED OPERATING INSTRUCTIONS EXPANDED SCALE pH METER

pH Standardization Procedure

1. Depress STANDBY push-button.
2. Set Temperature Compensator Switch at MAN.
3. Rinse thermometer and electrodes.
4. Immerse thermometer and electrodes in correct buffer.
5. Set TEMP °C at buffer temperature.
6. Depress pH and either STD or EXP push-buttons.
7. Rotate ASYMM until meter reads pH of buffer.
8. If in expanded scale operation, set Range Indicator at correct 2 pH span.

Standard Scale pH Measurement

1. Standardize instrument on standard scale.
2. Depress STANDBY push-button.
3. Rinse thermometer and electrodes.
4. Immerse thermometer and electrodes in sample.
5. Set TEMP °C at sample temperature.
6. Depress pH and STD push-buttons.
7. READ pH OF SAMPLE ON STANDARD SCALE.

Expanded Scale pH Measurement

1. Standardize instrument on expanded scale.
2. Depress STANDBY push-button.
3. Rinse thermometer and electrodes.
4. Immerse thermometer and electrodes in sample.
5. Set TEMP °C at sample temperature. (For spans other than 6-8 pH, sample temperature must be same as buffer used to standardize.)
6. Depress pH and EXP push-buttons.
7. READ pH OF SAMPLE ON EXPANDED SCALE.

Standard Scale Potential Measurement

1. Depress STANDBY push-button.
2. Insert 700 Terminal Connector into INPUT terminal and connect 8980 Shorting Strap between INPUT and REFERENCE terminals.
3. Depress STD and appropriate MV push-buttons.
4. Rotate ASYMM until meter reads zero.
5. Depress STANDBY push-button.
6. Connect electrodes.
7. Rinse electrodes.
8. Immerse electrodes in sample.
9. Depress appropriate MV push-button.
10. READ POTENTIAL ON STANDARD SCALE.
11. For measurements between 1400 and 2000 millivolts, refer to Paragraph 5.2 of Instruction Manual for scale shifting procedures.

Expanded Scale Potential Measurement

1. Depress STANDBY push-button.
2. Insert 700 Terminal Connector into INPUT terminal and connect 8980 Shorting Strap between INPUT and REFERENCE terminal.
3. Depress EXP and appropriate MV push-buttons.
4. Rotate ASYMM until meter reads at left-hand zero.
5. Depress STANDBY push-button.
6. Connect electrodes.
7. Rinse electrodes.
8. Immerse electrodes in sample.
9. Depress appropriate MV push-button.
10. READ POTENTIAL ON STANDARD SCALE.
11. For measurements between 200 and 1400 millivolts, refer to Paragraph 5.2 of Instruction Manual for scale shifting procedures.

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